

*Sponsored by the Office of Naval Research (ONR)*

**ONR Decision-Support Workshop Series**

# ***Interoperability***

hosted by the

**Collaborative Agent Design Research Center (CADRC)  
Cal Poly State University, San Luis Obispo, CA**

***Proceedings of Workshop held on September 8-9, 2004***

*at  
The Clubs at Quantico, Quantico Marine Base  
Quantico, VA*

November 2004



Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>17 DEC 2004</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Annual ONR Workshop on Collaborative Decision-Support Systems (6th) Held in Quantico, Virginia on 8-9 September 2004</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Collaborative Agent Design Research Center (CADRC) Cal Poly State University, San Luis Obispo, CA</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADM001754.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>UU</b>	18. NUMBER OF PAGES <b>177</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			







## Preamble

In August of 1998 the Collaborative Agent Design Research Center (CADRC) of the California Polytechnic State University in San Luis Obispo (Cal Poly), approached Dr. Phillip Abraham of the Office of Naval Research (ONR) with the proposal for an annual workshop focusing on emerging concepts in decision-support systems for military applications. The proposal was considered timely by the ONR *Logistics* Program Office for at least two reasons. First, rapid advances in information systems technology over the past decade had produced distributed collaborative computer-assistance capabilities with profound potential for providing meaningful support to military decision makers. Indeed, some systems based on these new capabilities such as the Integrated Marine Multi-Agent Command and Control System (IMMACCS) and the Integrated Computerized Deployment System (ICODES) had already reached the field-testing and final product stages, respectively.

Second, over the past two decades the US Navy and Marine Corps had been increasingly challenged by missions demanding the rapid deployment of forces into hostile or devastated territories with minimum or non-existent indigenous support capabilities. Under these conditions Marine Corps forces had to rely mostly, if not entirely, on sea-based support and sustainment operations. Particularly today, operational strategies such as Operational Maneuver From The Sea (OMFTS) and Sea To Objective Maneuver (STOM) are very much in need of intelligent, near real-time and adaptive decision-support tools to assist military commanders and their staff under conditions of rapid change and overwhelming data loads.

In the light of these developments the *Logistics* Program Office of ONR considered it timely to provide an annual forum for the interchange of ideas, needs and concepts that would address the decision-support requirements and opportunities in combined Navy and Marine Corps sea-based warfare and humanitarian relief operations. The first ONR Workshop was held April 20-22, 1999 at the Embassy Suites Hotel in San Luis Obispo, California. It focused on advances in technology with particular emphasis on an emerging family of powerful computer-based tools, and concluded that the most able members of this family of tools appear to be computer-based agents that are capable of communicating within a virtual environment of the real world. From 2001 onward the venue of the Workshop moved from the West Coast to Washington, and in 2003 the sponsorship was taken over by ONR's *Littoral Combat/Power Projection (FNC)* Program Office (Program Manager: Mr. Barry Blumenthal). Themes and keynote speakers of past Workshops have included:

**1999: ‘Collaborative Decision Making Tools’**

Vadm Jerry Tuttle (USN Ret.); LtGen Paul Van Riper (USMC Ret.); Radm Leland Kollmorgen (USN Ret.); and, Dr. Gary Klein (Klein Associates)

**2000: ‘The Human-Computer Partnership in Decision-Support’**

Dr. Ronald DeMarco (Associate Technical Director, ONR); Radm Charles Munns; Col Robert Schmidle; and, Col Ray Cole (USMC Ret.)

**2001: ‘Continuing the Revolution in Military Affairs’**

Mr. Andrew Marshall (Director, Office of Net Assessment, OSD); and, Radm Jay M. Cohen (Chief of Naval Research, ONR)

**2002: ‘Transformation ...’**



Vadm Jerry Tuttle (USN Ret.); and, Steve Cooper (CIO, Office of Homeland Security)

**2003: ‘*Developing the New Infostructure*’**

Richard P. Lee (Assistant Deputy Under Secretary, OSD); and, Michael O’Neil (Boeing)

**2004: ‘*Interoperability*’**

MajGen Bradley M. Lott (USMC), Deputy Commanding General, Marine Corps Combat Development Command; Donald Diggs, Director, C2 Policy, OASD (NII)

**Copies of the proceedings of past Workshops are available free of charge from:**

CAD Research Center (Bdg.117T), Cal Poly, San Luis Obispo, CA 93407  
(Attn.: ONR Workshop Proceedings)



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## **Opening Remarks**

### **as a Foreword to the 6<sup>th</sup> Annual Office of Naval Research (ONR) Workshop**

Good morning and welcome to this 6<sup>th</sup> annual Office of Naval Research Collaborative Decision-Support Systems Conference and Workshop. I am Jens Pohl, Executive Director of the Collaborative Agent Design Research Center at California Polytechnic State University, which we always refer to as Cal Poly, San Luis Obispo. We have had the honor of hosting this conference since 1999, and I thank you for your participation this year. I believe we again have an excellent group of presenters for these two days and we can all look forward to a very stimulating conference.

Perhaps I should start off by saying a few words about the purpose of these conferences. First and foremost these conferences are intended to help us shape an understanding and vision of the rapidly advancing information technology, advances for which we appear to have an increasing need. The underlying reasons for this need and the kind of capabilities that the technology can provide us with are the subject of the next two days. We are in fact at the beginning of a paradigm shift, transitioning our view of computers as dumb data processing devices to collaborative partners with some level of intelligence. The appropriate application of this powerful new technology involves all of us in a team effort of major proportions. Therefore this conference brings together representatives from three communities that have an important stake in information technology. First, the military and civilian users who use information technology as a critical decision making capability. Second, the government agencies that support the development and integration of information technology and that includes the government laboratories and I guess I would like to include in that also the universities that are conducting research. And third, industry, which actually develops most of the information technology products.

For the past two years this conference has been sponsored by Mr. Barry Blumenthal, program manager of the Littoral Combat Power Projection Full Naval Capabilities (FNC) Program. Barry, thank you for your continuing support in sponsoring the conference again this year.

At this point it was going to be my very genuine pleasure to introduce to you the person who conceived this conference series more than six years ago, Dr. Phillip Abraham. Sadly, Phil became ill a few days ago. He called me to say that on the advice of his doctor he could not attend the conference this week. Phil Abraham foresaw that we were at the threshold of a new generation of computer software, with potential capabilities far exceeding those that were in existence in 1998. All I can say is, Phil, how right you were and please recover quickly there is still a great deal to accomplish.

You notice the word *collaboration* in the title of the conference series and also in the name of our research center at Cal Poly, San Luis Obispo. Recently I received a telephone call from a gentleman whose name I was familiar with, although I had not met him previously. However, I had read some of his papers. He came straight to the point, wanting to know the significance of the word *collaboration* when used in conjunction with decision-support software. He asked: "How can collaboration by software agents lead to problem solving?" His question took me a little by surprise and I had to gather my thoughts before replying. My reply was in two parts. First, the use of the word *collaboration* suggests a need to view a problem situation from several points of view. It further suggests a degree of uncertainty and a likelihood of conflicting viewpoints. In other words, the final decision is unlikely to be an optimum solution but rather an acceptable solution. Therefore, there is a need for negotiation in a collaborative environment. Second, the computer environment is really a virtual environment. It is a virtual representation of our human environment. I readily admit that today this virtual environment is still a far cry from the complexity and richness of the human environment. However, that is changing and those changes will be the focus of the presentations and discussions of the next two days. Computer software is rapidly gaining in



capabilities and there is no question in my mind that we are rapidly transitioning to a very powerful virtual decision-support environment. I further believe that much of the power of this virtual environment will depend on the ability of its various intelligent components, we call them agents these days, to collaborate with each other and us human users. This then leads me into my introductory presentation for this year's conference, *Interoperability and the Need for Intelligent Software*.

Jens Pohl, Executive Director  
Collaborative Agent Design Research Center (CADRC),  
California Polytechnic State University (Cal Poly), San Luis Obispo  
Quantico, September 8, 2004





## Sixth Annual ONR / CADRC Decision-Support Workshop

September 8-9, 2004, Quantico, Virginia

**The Office of Naval Research**  
and  
**The Collaborative Agent Design Research Center**  
Cal Poly, San Luis Obispo

### *"Interoperability"*

*War Fighting and Homeland Security Expectations in a Net-Centric Decision-Support Environment*

*..... Architectural Issues of the Global Information Grid (GIG)*

*..... Multilateral Interoperability Programme (MIP) and C2IEDM*

*..... Taxonomies, Logical Data Models, and Ontologies*

*..... Coalition Interoperability at the 'Information' Level*

*..... Collaborative Intelligent Software Agents*

*..... The Communication Infrastructure*

*..... Government Plans, Initiatives, and Obstacles*

#### **Wednesday, September 8:**

Time	Activity
7:15	<b>Check-in and Registration Begins</b> Registration Desk open from 7:15 AM to 5:00 PM
8:15 – 8:30	<b>Opening Remarks and Welcome</b> <b>Dr. Jens Pohl</b> , Executive Director, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo, CA
8:30 – 8:45	<b>Why this Conference?</b> <b>Dr. Phillip Abraham</b> , Naval Research Laboratory, Physical Acoustics Branch, Washington, DC
8:45 – 9:45	<b>Introduction of Conference Theme: "Interoperability and the Need for Intelligent Software"</b> <b>Dr. Jens Pohl</b> , Executive Director, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo, CA
9:45 – 10:00	<b>Break</b>



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**Wednesday, September 8 (continued):**

<b>Time</b>	<b>Activity</b>
<b>10:00 – 10:30</b>	<b><i>"Delivering Joint and Coalition Interoperability at the Information Level"</i></b> <b>LCol. Jacques Hamel</b> , The Canadian Forces, PM ISTAR, Ottawa, Canada
<b>10:30 – 11:00</b>	<b><i>" Levels of Interoperability "</i></b> <b>Dr. Peter C. Bahrs</b> , IBM Corporation, Austin TX <b>and Dr. Christopher Codella</b> , IBM Corporation, Hawthorne NY
<b>11:00 – 11:30</b>	<b><i>"Interoperability Cost Estimation"</i></b> <b>Dr. Conrad Strack</b> , CSCI, Springfield, VA
<b>11:30 – 12:00</b>	<b><i>" Information and Global Integration"</i></b> <b>Col. Robert Morris</b> (USA), Director, Decision Superiority Dept., JFCOM, Suffolk, VA
<b>12:00 – 1:15</b>	<b>Lunch</b>
<b>1:15 – 1:45</b>	<b><i>"The C2 CoI as the Foundation for Joint, Multinational, and Inter-agency Interoperability "</i></b> <b>Mr. Erik Chaum</b> , Naval Sea Systems Command, Warfare Center, Division Newport. RI
<b>1:45 – 2:15</b>	<b><i>"Data Mediation Services Based on the C2IEDM - Migration of Legacy Systems into Service-Oriented Architectures "</i></b> <b>Dr. Andreas Tolks</b> , Virginia Modeling Analysis and Simulation Center, Old Dominion University, Norfolk, VA
<b>2:15 – 2:45</b>	<b><i>"Battle Management Language - Enabling Semantic Interoperability"</i></b> <b>Dr. Michael Hieb</b> , ALION Science and Technology, McLean, VA
<b>2:45 – 3:00</b>	<b>Break</b>
<b>3:00 – 3:30</b>	<b><i>"Semantic Mediation Tools for Interoperability"</i></b> <b>Ms. Mala Mehrotra</b> , Pragati, Inc., San Jose, CA
<b>3:30 – 4:00</b>	<b><i>"Generative Ontologies for Extracting Concepts from Text Documents"</i></b> <b>Dr. David W. Aha</b> , Naval Research Laboratory, Washington, DC
<b>4:00 – 4:30</b>	<b><i>"Challenging Old Assumptions in Global Information Access"</i></b> <b>Dr. Van Parunak</b> , Altarum Institute, Ann Arbor, MI
<b>4:30 – 5:00</b>	<b><i>"The Multilateral Interoperability Programme (MIP) - Coalition Sharing of Information in Context"</i></b> <b>Mr. Paul Ulrich</b> , Shonborn Becker Systems, Inc., Union, NJ
<b>5:00</b>	<b>(CLOSE DAY ONE)</b>
<b>5:00 – 7:00</b>	<b>No Host Social</b>
<b>7:00 – 9:00</b>	<b>Speakers' Dinner In the Waller Room (by invitation)</b>



## ***Thursday, September 9:***

<b>Time</b>	<b>Activity</b>
<b>7:15 - 12:00</b>	<b>Check-in and Registration Continues</b> Registration Desk open from 7:15 AM to noon
<b>7:55 - 8:00</b>	<b>Announcements</b> <b>Dr. Jens Pohl</b> , Executive Director, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo, CA
<b>8:00 – 8:45</b>	<b>Keynote: "Posturing to Exploit the Power of Emerging Technology"</b> <b>MGen Bradley M. Lott</b> (USMC), Deputy Commanding General, Marine Corps Combat Development Command, Quantico, VA
<b>9:00 – 9:45</b>	<b>Keynote: "Information Integration and Decision Support"</b> <b>Mr. Donald Diggs</b> , Director, C2 Policy, OASD (NII), Washington, DC
<b>9:45 – 10:00</b>	<b>Break</b>
<b>10:00 – 10:30</b>	<b>"Coalition Command and Control: The COSMOS ACTD as an Agent for Change"</b> <b>Col. Kevin Jordan</b> (USMC ), PACOM
<b>10:30 – 11:00</b>	<b>"Network Security Issues for the GIG"</b> <b>Dr. Scott Hansen</b> , Northrop Grumman Defense Missile Systems, Reston, VA
<b>11:00 – 11:30</b>	<b>"Global Information Integration and Decision (GIID) Portfolio."</b> <b>Mr. Peter Trask</b> , Johns Hopkins University, APL, Laurel, MD
<b>11:30 – 12:00</b>	<b>"Cross Agency Collaboration - JWID '04 Experience"</b> <b>Mr. David Waxman</b> , IBM, Hawthorne, NY
<b>12:00 – 1:15</b>	<b>Lunch</b>
<b>1:15 – 1:45</b>	<b>"Game Theoretic Models for Reliable Optimal Routing for Data Aggregation in Wireless Sensor Networks"</b> <b>Dr. S.S. Iyengar</b> , Roy Paul Daniels Professor, Louisiana State University, Baton Rouge, LA
<b>1:45 – 2:15</b>	<b>"Automated Decision Support for Architectures"</b> <b>Dr. Steven Wartik and Dr. Francisco Loaiza</b> , Institute for Defense Analyses, Alexandria, VA
<b>2:15 – 2:45</b>	<b>"Use of XML-Based C2IEDM Interchange and XML Tactical Chat (XTC) for Global Interoperability"</b> <b>Dr. Don Brutzman</b> , Naval Postgraduate School, Monterey, CA
<b>2:45</b>	<b>Workshop Wrapup</b> <b>Dr. Jens Pohl</b> , Executive Director, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo, CA
<b>(CLOSE DAY TWO)</b>	







## ***About the Authors***

### **Dr. Phillip Abraham Physical Acoustics Branch Office of Naval Research**

Dr. Abraham is a Scientific Officer at the Office of Naval Research (ONR). For the last two years he has been on assignment at the Physical Acoustics Branch, and for the eight years before that, starting in 1994, he managed the ONR Science and Technology (S&T) Logistics Program. A major endeavor during these years was the introduction of S&T projects in a program that at the time depended on old technologies. In this he was guided by the view that the goal of military logistics is readiness everywhere, at all times. Toward this goal he introduced state-of-the-art sensors (e.g., MEMS), intelligent agents for decision support systems, and other innovations in both hardware and processes. Under his management the Logistics Program has addressed a host of areas that needed S&T attention. These included Maintenance (where sensor monitoring and diagnostics of systems replaces fixed schedule checkups and overhauls), Underway Replenishment (the goal being operation in sea states 3 and higher via technical improvements to existing crane systems, as well as the development of new systems that will eventually replace the conventional cranes), Amphibious Logistics (Seabasing is the major goal here and the tools that will enable the integration of the sea and shore operations are the SEAWAY and LOGGY projects that have received support from both the Navy and the Marine Corps), Naval Facilities (the major thrusts in this area were the operation of the naval bases, the rehabilitation of the deteriorating naval piers, the design of modular hybrid piers, and the design and construction of high performance ordnance magazines), Decision Support Systems (the goal in this area is to provide to the CO, at any level of command, a decision system based on state-of-the-art

collaborative intelligent agents and tailored to the needs of that level), and Integration (the goal here is the integration of all the systems on a single navy platform, a squadron, a battle group, a fleet, &c., that will result in the highest achievable state of readiness. A current project, "Mission Readiness Analysis", addresses the challenge of systems integration on a single platform).

Dr. Abraham joined the Office of Naval Research in 1989 as a member of the Mechanics Division where he was in charge of the ONR 6.1 Structural Acoustics Program, the goal of which was minimizing the emission and scattering of sound by submarines. Based on his own prior work while employed by Raytheon Co. (see below), he introduced the idea of working in the time domain in computations related to the response of complex elastic structures to internal and external excitations. This allowed the computation of the response of models of submarines with internal structure in (almost) real time and reduced the demands on computer hardware. This work was performed at the University of Texas (Austin) and Stanford University (Palo Alto) using the most sophisticated computational techniques (of the time) for large scale problems.

From 1982 until 1989 Dr. Abraham was a member of the Naval Research Laboratory where he did research on fluid-structure interactions, and on wave propagation phenomena. He studied the propagation of acoustic waves in inhomogeneous and random media, and showed how to obtain results, to all orders, for both weak and strong inhomogeneities. This work, and work on reflection tomography, were motivated by the need to detect passively or actively targets in regions of the ocean that are contaminated by random distributions of biological and other scatterers.



In 1974 Dr. Abraham started working at the Naval Underwater Sound Laboratory in New London, Connecticut. There his research dealt with underwater acoustics, focusing on detection and localization of underwater targets. Among other topics, he determined the influence of size on magnetic anomaly detection (MAD) of ferromagnetic targets (such as submarines). In addition he, and Dr. H. Moses, used inverse scattering theory to generate new families of sound velocity profiles (in the ocean) for which the wave equation has exact solutions. These were useful later on in determining acoustic wave propagation in the arctic ice cap. This work also led to concurrent results for potentials appearing in the Schrodinger equation of Quantum Mechanics. One of these potentials, a nontrivial modification of the harmonic oscillator potential, has been referred in the literature as the Abraham-Moses potential.

From 1970 until 1974, Dr. Abraham was an Assistant Professor of Physics at the University of Connecticut, where he taught and worked on Nonlinear Dynamics problems related to solitons.

During 1968-1970, Dr. Abraham was employed by Raytheon Company in New London, Connecticut. There he worked on acoustic imaging in fluid media using an exact analytic approach for solving wave equations in the time domain. A concurrent laboratory experiment yielded a visual image, on a TV screen, of an insonified, submerged object. At that time, it was the first such image generated with acoustic waves.

In 1966 Dr. Abraham was granted a Postdoctoral Research Associateship by the National Research Council. Located at NASA's Goddard Space Flight Center, he worked on propagation of charged particles (originating from solar flares) through the interplanetary magnetic field. The results of

the theoretical work matched quite well with experimental results obtained from high-altitude balloon flights.

Dr. Abraham was awarded the Ph.D. in Physics by the University of Maryland in 1966. His thesis topic was in Solid State Physics, and it dealt with generating exactly solvable models of crystal lattices, which were used subsequently to check perturbation methods employed in the treatment of actual crystals. Among the results obtained was a new method of evaluating finite and infinite sums that appear in various areas of physics.

In 1960, Dr. Abraham was awarded the M.Sc. degree in Physics by the Hebrew University in Jerusalem, Israel. His Master Thesis (in atomic spectroscopy) dealt with the computation of the energy levels of isoelectronic sequences of atoms in various configurations. The results of these computations reside in the tables published during the sixties by NIST (then NBS), under the editorship of Dr. Charlotte Moore.

### **Dr. David W. Aha Computer Scientist Naval Research Laboratory**

David W. Aha leads NRL's Intelligent Decision Aids Group, whose focus is on the research and development of state-of-the-art decision aiding tools that can be transitioned to their sponsors' organizations. He currently leads projects concerning knowledge extraction from text documents, deviation detection for crisis action planning, hypothesis elaboration for suspected terrorist activities, learning in the context of (gaming) simulators, and plan de-confliction and air vehicle management. His focal research interests include case-based reasoning, machine learning, mixed-initiative planning, and knowledge management (e.g., intelligent lessons



learned systems). David has organized 13 international conferences/workshops, served on the editorial boards for *JAIR*, *Machine Learning*, and *Applied Intelligence*, edited two special journal issues, and serves on several AI conference program committees.

**Dr. Peter Bahrs**  
**Distinguished Engineer**  
**IBM Corporation**

Dr. Peter C. Bahrs is an IBM Distinguished Engineer. He currently serves as an IBM IT architect for the US Air Force and US Navy, developing architecture and application strategies based on COTS and Open Standards implementations. He has participated in the Navy OA review workshop, ForceNet review, and C4ISR summit sub-panel member on commercial standards / infrastructure for net-centricity.

Dr. Bahrs serves on the IBM Software Group Architecture Board participating in Solutions, Open Standards, Branch Banking Renewal, and Software Componentization workgroups. He holds six US patents with fourteen pending, and has numerous publications. He has a PhD, MS, and BS in computer science from the University of Louisiana.

Dr. Bahrs has served six years as an IT architect in software services specializing in the development and deployment of large scale transformations of mission critical commercial banking systems at USAA, MBNA, UBS Switzerland, KBC Belgium, and CIBC Canada. These systems support millions of users 24/7 with huge transaction loads.

Dr. Bahrs has deep technical skills in architecture development and implementation including applied knowledge of BPML, J2EE, Web Services, Eclipse, UML,

Portal, enterprise integration, interoperability levels, and large-scale business transformation. He has specialist experience in the IBM product portfolio including WebSphere, Business Integrator, Portal, DB2, Information Integrator, Studio, and Rational.

**Dr. Don Brutzman**  
**Technical Director for 3D Visual**  
**Simulation**  
**Naval Postgraduate School**

Don Brutzman is Technical Director for 3D Visual Simulation and Networked Virtual Environments in the MOVES Institute. As an Associate Professor at the Naval Postgraduate School in Monterey California, he is a member of two Academic Groups: Undersea Warfare (UW) and Modeling, Virtual Environments and Simulation (MOVES). He is an investigator in the NPS Center for Autonomous Underwater Vehicle (AUV) Research. His research interests include underwater robotics, real-time 3D computer graphics, artificial intelligence and highperformance networking. He is a member of the Institute of Electrical and Electronic Engineers (IEEE), the Association for Computing Machinery (ACM) Special Interest Group on Graphics (SIGGRAPH) and the American Association for Artificial Intelligence (AAAI).

Professor Brutzman is a founding member of the non-profit Web3D Consortium Board of Directors. He represents Web3D as the Advisory Committee Representative to the World Wide Web Consortium (W3C). Together with research associate Don McGregor, he designed and developed the influential DIS-Java-VRML open-source implementation of the Distributed Interactive Simulation (DIS) protocol, thus enabling shared multi-user virtual worlds via regular Web browsers. Currently he leads the VRML 200x / Extensible 3D (X3D)



Graphics Specification Task Group. X3D is the third-generation version of the Virtual Reality Modeling Language (VRML) international standard. He further directs development of the virtual reality transfer protocol (vrtp), designed to integrate the necessary network functionality (client, server, peer-to-peer multicast and network monitoring) for large-scale Web-based virtual environments.

Professor Brutzman is a board member of non-profit Sea Lab Monterey Bay, which is designing and building a youth-oriented year-round residential science camp. This partnership includes participation and support from over two-dozen research and educational institutions around Monterey Bay. He also leads the SIGGRAPH Online effort, which will record and publish over 100 hours of instructional video, papers and slidesets via Web-based multimedia distribution.

Dr. Brutzman is a retired submarine officer who has conducted testing of advanced capability underwater equipment. Current research work includes the development of underwater robot software, in combination with comprehensive virtual-world modeling of underwater hydrodynamics, sonar and robot hardware response. This physics-based virtual world development supports the Acoustic-Radio Interactive Exploratory Server (ARIES), a highly capable fourth-generation Autonomous Underwater Vehicle (AUV) designed, built and operated at NPS. In related work, he co-directs the Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) research project, which is modeling a joint amphibious raid and showing how 3D virtual environments can be automatically generated from operations orders. Together these many efforts will elevate interactive networked 3D graphics to become an open, first-class media type supporting science and education on the World Wide Web.

**Mr. Erik Chaum**  
**Principal Investigator**  
**Naval Undersea Warfare Center,**  
**Newport RI**

Erik Chaum is a Principal Investigator within the Combat Systems Department at Naval Undersea Warfare Center (NUWC), Division Newport. He serves as a Naval Sea Systems Command (NAVSEA) representative in the Systems Command Liaison Office at the Office of Naval Research (ONR) and is the U.S. National Leader of The Technical Cooperation Program (TTCP), Maritime Systems Group, Technical Panel One (Maritime Command and Control and Information Management).

Mr. Chaum joined NUWC in 1986 and has worked on a wide range of advanced information system concepts and capabilities. He has lead NUWC's recent virtual submarine participation in Navy Fleet Battle Experiments Golf, India, Juliet and Kilo. The virtual submarines, manned with military crews, have been exploring submarine roles in a network-centric Joint force. He has been working collaboratively with the Office of the Secretary of Defense, Joint Forces Command, the Army, and other Navy commands on transformational approaches to improve interoperability and net-centric warfare capabilities. This has been motivated and informed by his interest and involvement in the activities of the Multilateral Interoperability Programme (MIP) and its Command and Control Information Exchange Data Model (C2IEDM).

Mr. Chaum is a graduate of the U.S. Naval Academy (1977) and subsequently served on USS Harold E Holt (FF 1074) as Anti-Submarine Warfare Officer. He then taught cruise missile employment at Fleet Training Group, Pearl Harbor, HI. On leaving active duty he attended Management of Technology program at the Massachusetts



Institute of Technology (1984). Mr. Chaum continued his military career in the Naval Reserve serving for ten years with the Office of Naval Research and then for five years at the Naval War Gaming Department at the Naval War College, Newport RI. He retired from the Reserves in 1998.

He and his wife Meryl live in Portsmouth, Rhode Island.

**Dr. Christopher F. Codella**  
**Deputy Chief Technology Officer**  
**IBM**

Christopher F. Codella is Deputy Chief Technology Officer for IBM Federal, Software Group. Dr. Codella received a B.S. degree from Rutgers University in 1977, an M.S.E. from the University of Michigan in 1978, and a Ph.D. from Cornell University in 1984, all in Electrical Engineering. His dissertation work focused on fabrication, characterization and numerical simulation of compound semiconductor field-effect transistors. From 1979 to 1989 he worked at IBM in East Fishkill, NY and Yorktown Heights, NY doing NMOS and CMOS device and process design using numerical simulation and analysis, and developing device models for computer based circuit and chip design.

In 1989 he became a Research Staff Member in the Computer Science Department at the IBM T. J. Watson Research Center where he was the manager of the Virtual Worlds Group developing software for collaborative virtual environments. During 1996 he worked in the IBM Consulting Group on assignment, developing a framework for reuse of models and code across the services sectors. Recently he was senior manager of the Enterprise Middleware department, which does research and advanced development in object-oriented software technology,

distributed systems, reusable software components and component architecture. The group has contributed many innovative software technologies that have become part of IBM's middleware products including WebSphere, Component Broker, and MQ Series. He received IBM's Outstanding Technical Achievement Award for his contributions to Enterprise Java. Before joining IBM Federal, he was on a one-year assignment to the Research Division headquarters staff where he led the development of IBM Research's 2003 Global Technology Outlook, a study of industry and technology trends that helps set the corporate technical strategy.

Dr. Codella is a Senior Member of the Institute of Electrical and Electronics Engineers, author of a number of professional publications and conference papers, and holder of several US patents. He lives with his wife and two sons in New York's Hudson River Valley.

**Mr. Donald Diggs, IPA (SES-2)**  
**OASD (NII), Director, C2 Policy**

Don Diggs, Director C2 Policy, is responsible for guiding development of policies and doctrine for United States military Command and Control (C2) and business-enterprise continuity, as well as concept development for net-centric enterprise-wide information integration and continuity.

Mr. Diggs attended the United States Naval Academy where he earned a Bachelor of Science Degree in International Security Affairs. Following graduation, he was commissioned in the Navy where his principal operational experience was in aviation, flying strategic communications aircraft in both the Pacific and Atlantic Fleets. He was selected to establish the Operations Department in the Navy's newly-commissioned Strategic Communications



Wing ONE at Tinker AFB, Oklahoma, where he was instrumental in establishing a Commander Task Force (CTF) element of the U.S. Strategic Command. Following this assignment, he was assigned as Squadron Commanding Officer where he spearheaded a Naval Aviation squadron transition with “no operational stand-down” to a new airframe. Mr. Diggs was then assigned to Chief of Naval Operations where he led development of an E-6 Aircraft Roadmap resulting in a commitment of over \$1 billion to ensure critical national command and control aircraft continued to serve national security priorities well into the next century. Mr. Diggs also attended and graduated from the U.S. Naval War College with a Master of Arts in National Security and Strategic Studies.

In March 2003, Mr. Diggs retired from the Navy after his assignment to the Office of the Secretary of Defense as Acting Director for C2 Policy overseeing a variety of Department of Defense C2 issues including development of national C2 architectures and implementing C2 policy for net-centric operations. He was the primary OSD advocate for Executive Agent responsibilities supporting the White House Military Office with oversight of a wide range of DoD command and control assets. In the aftermath of September 11<sup>th</sup>, he was responsible for over \$500 million of supplemental funding which led to improvements in Presidential, Secretary of Defense, and other Senior Leader fixed and mobile communications infrastructures. He also led the efforts of the Services and multiple agencies in the design, integration and deployment of critical and sensitive C2 capabilities to multiple operational locations across the greater National Capital Region.

Mr. Diggs is currently active in development of National and Department of Defense Command and Control concepts in support of the nation’s senior leadership and in

support of both nuclear and non-nuclear strike and defenses.

### **Lieutenant-Colonel Jacques Hamel, CD, Eng The Canadian Forces, PM ISTAR**

LCol Jacques Hamel joined the Canadian Forces in 1977 as an Engineer Officer. He Graduated in 1982 from the Royal Military College in Kingston with an Honour Degree in Engineering Physics. In 1982 he joined the 5e Régiment du génie de combat (5th Combat Engineer Regiment) in Valcartier, where he served over a number of regimental assignment as a Troop Commander, Adjutant, Squadron Commander and Deputy Commanding Officer until 1990.

From 1991 to 1993 LCol Hamel served in National Defence HQ on the J3 Engineer Staff as a Project Director for a wide range on Combat Engineering, Command and Control automation and Geomatics Capital Projects and as the J3 Engineer-Sustainment on the Joint Staff. In 1994 LCol Hamel was appointed G3 Plans In Army HQ where he was responsible for all international and contingency planning for the Canadian Army.

In 1997 LCol Hamel was appointed to the Directorate of Army Doctrine as the section head responsible for force protection doctrine and as Acting Director of Army Doctrine during 1998. In 1999 LCol Hamel Joined the Army Strategic Concept staff as the Director of the Army Experimentation Centre and he became the Canadian Head of delegation to the ATCCIS study.

From 2000 to 2003 LCol Hamel was the Program Manager of the Canadian Land Force Command and Control Information System (LFC2IS) and internationally acted



as the Chairman of the MIP Data and Procedure Working Group.

In 2003 LCol Hamel was appointed to his current appointment of Project Manager Intelligence Surveillance, Target Acquisition and Reconnaissance (ISTAR) Omnibus where he is responsible for the implementation of the Army C4ISR Projects. Internationally he is active in the CANUS C4ISR interoperability and in the MAJIIC program.

LCol Hamel is a Professional Engineer with l'Ordre des Ingénieurs du Québec, a graduate of the Canadian Land Force Command and Staff College in Kingston, of the UK Royal Military College of Science in Shrivenham and of the UK Army Command and Staff Course in Camberley.

**Dr. D. Scott Hansen**  
**Assistant Vice President for C4I**  
**Northrop Grumman**

Dr. Hansen holds a B.S in Engineering Physics from Oregon State University, a MS in Applied Mathematics from UC, San Diego, and a Ph.D in Oceanography from Scripps. He presently holds the position of Senior Program Manager at Northrop Grumman Corporation.

Dr. Hansen is participating in several strategic initiatives related to DoD and DHS program development as DoD and civil sectors of the government develop US Homeland Security and Defense programs. Dr. Hansen is also assisting various DoD/Civil Wireless initiatives in defining program scope and technical concepts. Dr. Hansen is working initiatives between DoD and HLS/DHS netcentric activities. Many issues related to fundamentals privacy are security are being studied as part of these efforts.

Before joining Northrop Grumman, Dr. Hansen was Senior Engineer with Science Applications International Corporation where he participated technically and in varying management roles in a wide range of C4ISR and Network Centric Warfare Programs supported by state of the Art Modeling and Simulation Systems. These programs include the Defense Advanced Research Projects Agency (DARPA) Simulation, Evaluation and Management of Mobile and fixed Networking technologies being used to support analyses for the Future Combat System, Objective Force, Interim Brigade Combat Teams, Joint Virtual Battlespace, Ship-to-Objective Maneuver and several related activities supporting defining standards and architectures for the Joint Tactical Radio System in warfighting, and Homeland Security and Defense roles.

Dr. Hansen has also been heavily involved in assessing and developing Military, Interagency and Civilian preparedness and response capabilities for NBCRE operations. Dr. Hansen has participated in National and International Congressionally mandated assessments of the National infrastructure to mitigate the effects of NBCRE asymmetric attacks and other terrorists operations for Domestic and International facilities. In particular, Dr. Hansen has been involved in assessing (nationally and internationally) and developing draft policies, processes and C4ISR infrastructure in government, military, business and health care sectors that enable responding to these classes of threats. Dr. Hansen was the author of the C4ISR and Telecommunications sections of the Report to the National Guard Bureau Weapons of Mass Destruction report to Congress. Also in this arena, Dr. Hansen, is an expert in operational interoperability between Napoleonic and Incident Command System staff organizations.



Prior to being involved with the Joint Countermine ACTD initiated in 1995, Dr. Hansen was heavily involved in developing the US Navy's Mine Warfare C4ISR Architecture. In support of this effort Dr. Hansen coordinated closely with N6, N85, Program Executive Officer for Mine Warfare (PEO-MIW), Commander Mine Warfare Command (CMWC), Naval Doctrine Command, Naval Command and Control Oceanographic System Command, Coastal System Command and several components of SPAWAR to develop an inclusive architecture under the Copernican guidelines.

Dr. Hansen also led the Demonstration and Integration team as the Chief Scientist for the US Navy for the Air Defense Initiative (ADI). This Joint CONUS Defense Program, part of the Strategic Defense Initiative, with extensive participation from SPACECOM, NORAD, PACOM and USACOM culminated in a series of dedicated and leveraged field experimental programs where Dr. Hansen served as Chief Scientist and directed all phases of these complex operations. Much of the technical effort for this program focused on data fusion of dissimilar C4ISR phenomenology. Specialized correlation algorithms were implemented within the Joint Maritime Command and Information System (JMCIS) to support many of these field demonstrations and laboratory analysis.

At BBN Systems and Technology Corporation from 1984 to 1988, Dr. Hansen participated and managed efforts related to theoretical and/or field studies for active and passive detection of undersea platforms from surface and subsurface detection systems. These studies generally included threat envelope assessments, "wet" end sensitivity/performance considerations, ambient noise/reverberation issues, signal processing performance, and finally operator/display performance. In support of

these studies Dr. Hansen led teams of analysts and system implementors for prototype detection systems. Programs involved in these efforts included Low Frequency Active (LFA) including its Low Low variant (LLFA), Fixed/Fixed I-III, Glenngarry I and II and Overbid Leo for active systems and primarily the Fixed Distributed System (FDS) for passive systems. Dr. Hansen and the teams he led researched the performance envelope of advanced signal processing systems/algorithms including varying waveforms, normalization approaches, reverberation cancellation filtering and continuous wave barrier approaches for active systems. For passive systems team efforts included signature analysis of special platforms, Adaptive and Conventional Beamforming, array design, broadband cross and autocorrelation systems and narrowband phase tracking.

**Dr. Michael Hieb**  
**Assistant Vice President for C4I**  
**Programs, Alion Science and**  
**Technology**

Michael Hieb is an Assistant Vice President for C4I Programs for Alion Science and Technology. Dr. Hieb is currently an Architect for the Army SIMCI OIPT. He received his Ph.D. in Information Technology at George Mason University in 1996 and performed his doctoral research at the GMU Center for Excellence in C3I. Dr. Hieb received his MS degree in Engineering Management from George Washington University and his BS degree in Nuclear Engineering from the University of California in Santa Barbara. He has published over 50 papers in the areas of M&S integration with C4I and Machine Learning. Previously, he worked as a Nuclear Engineer for General Electric.



**Dr. S.S. Iyengar**  
**Roy Paul Daniels Professor**  
**Louisiana State University**

Dr. S. S. Iyengar is the Chairman and Roy Paul Daniels Chaired Professor of Computer Science at Louisiana State University and is also Satish Dhawan Chaired Professor at Indian Institute of Science. He has been involved with research in high-performance algorithms, data structures, sensor fusion, data mining, and intelligent systems since receiving his Ph.D. degree (in 1974 at Mississippi State University) and his M.S. from the Indian Institute of Science (1970). He has directed over 30 Ph.D. candidates, many of whom are faculty at major universities worldwide or scientists or engineers at national labs/industry around the world. His publications include 13 books (authored or coauthored, edited; Prentice-Hall, CRC Press, IEEE Computer Society Press, John Wiley & Sons, etc.) and over 300 research papers in refereed journals and conference in areas of high-performance parallel and distributed algorithms and data structures for image processing and pattern recognition, and distributed data mining algorithms for biological databases. His books have been used by researchers at Purdue, University of Southern California, University of New Mexico, etc. at various times. He was a visiting professor at the Jet Propulsion Laboratory-Cal. Tech, Oak Ridge National Laboratory, the Indian Institute of Science, and at the University of Paris and other places. He has been on the prestigious National Institute of Health-NLM Review Committee, in the area of Medical Informatics for 4 years.

Dr. Iyengar was the winner of the IEEE Computer Society Technical Achievement Award for Outstanding Contributions to Data Structures and Algorithms in Image Processing and Sensor Fusion Problems. This is the most prestigious research award

from IEEE Computer Society. Dr. Iyengar was awarded the LSU Distinguished Faculty Award for Excellence in Research, the Hub Cotton Award for Faculty Excellence, and the LSU Tiger Athletic Foundation Teaching Award in 1996. He has been a consultant to several industrial and government organizations (JPL, NASA etc.). In 1999, Professor Iyengar won the most prestigious research award titled Distinguished Research Award and a university medal for his research contributions in optimal algorithms for sensor fusion/image processing.

He is also a Fellow of ACM, a Fellow of the IEEE, a Fellow of AAAS, IEEE Distinguished Visitor, etc. He received the Prestigious Distinguished Alumnus Award from Indian Institute of Science, Bangalore in 2003. Also, Elected Member of European Academy of Sciences (2002). He is a member of the New York Academy of Sciences. He has been the Program Chairman for many national/international conferences. He has given over 60 plenary talks and keynote lectures at numerous national and international conferences.

**Colonel Kevin B. Jordan**  
**USMC**

Colonel Jordan graduated from the University of Pennsylvania in 1972 with a BA in psychology, and was commissioned a second lieutenant through Officer Candidate School in 1976. He has attended Communication Officer School, the Marine Corps Command and Staff College, and the Armed Forces Staff College. He graduated with highest distinction from the Naval War College in June 1996 with an M.A. in National Security Studies. He was promoted to his current grade in October 1998.

Colonel Jordan's assignments over the past 25 years include serving as Commanding



Officer, Marine Communications Detachment, USS Blue Ridge; CINC Communications Officer, U.S. Central Command during Operation Desert Shield/Storm; Inspector/Instructor for the 6th Communication Battalion at Ft. Schuyler, NY; Central Command Desk Officer in the Current Operations Division of the Communications Directorate (J6) of the Joint Staff; Assistant Chief of Staff for Communications (G6) for the Marine Forces Reserve in New Orleans, LA; Commanding Officer, Headquarters & Service Battalion, Marine Forces Pacific; Assistant Chief of Staff/G6, Marine Forces Pacific. He served concurrently as the G-6 for Marine Forces Central Command as the senior communications strategist and war planner for Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), with additional responsibility and oversight for large C4 commercialization projects in Djibouti and Iraq. He is currently in charge of Operations & Plans in the J6 for U.S. Pacific Command, and concurrently serves as Operational Manager for the Coalition Secure Management and Operations System (COSMOS) Advanced Concept Technology Demonstration (ACTD).

Colonel Jordan's personal awards include the Legion of Merit, Bronze Star (2<sup>nd</sup> award), Joint Meritorious Service Medal (2<sup>nd</sup> award), Meritorious Service Medal (2<sup>nd</sup> award), Navy Commendation Medal (2<sup>nd</sup> award), and Navy Achievement Medal (2<sup>nd</sup> award).

Colonel Jordan is married to Dr. Dianne Hirata Jordan. They have two sons: Eamon, age 26, a graduate in electrical engineering from the University of Pennsylvania and an Air Force 1stLt assigned to the 606<sup>th</sup> Air Control Squadron based in Spangdalem, Germany; and Brendan, age 23, a graduate in economics from the University of Pennsylvania, now working for Oppenheimer & Co. in New York City.

## **Major General Bradley M. Lott Deputy Commanding General, Marine Corps Combat Development Command (MCCDC)**

Major General Lott is currently serving as the Deputy Commanding General, Marine Corps Combat Development Command, Quantico, Virginia. Additionally, he serves as the Marine Corps Principal Representative to the Joint Capabilities Board, which supports the Assistant Commandant of the Marine Corps and the Vice Chairman of the Joint Chiefs of Staff in carrying out their responsibilities with the Joint Requirements Oversight Council.

General Lott was commissioned through the Officer Candidates School in 1972 and after completing The Basic School he was assigned to the 2d Marine Division and later with Force Troops, Atlantic. In 1976, he was assigned to 9th Marine Regiment, 3d Marine Division.

During January 1979, General Lott was assigned to the staff of Officer Candidates School while awaiting the start of Amphibious Warfare School (AWS). Upon completion of AWS, he transferred to the 1st Force Service Support Group where he served as a Company Commander. In 1982, he was promoted to Major and assigned as a Battalion Executive Officer.

In 1983, he was assigned to the Joint U.S. Military Assistance Group-Korea as the Security Assistance Officer where he managed the contracts and accounts for major equipment and ammunition acquisition for the Republic of Korea Naval-Marine Forces.

In 1985, General Lott attended the Marine Corps Command and Staff College, followed by an assignment in the 1st Force Service Support Group. After promotion to Lieutenant Colonel in 1989, he assumed



command of MEU Service Support Group 13 and deployed to the Western Pacific where he participated in humanitarian relief operations in the Republic of the Philippines and in Operations Desert Shield and Desert Storm in the Middle East.

Upon returning to CONUS in 1991, General Lott was assigned as the Director, Materiel Division, Marine Corps Logistics Base, Albany, Georgia and then Commander, Defense Distribution Depot, Albany, Georgia, followed by attendance at the Industrial College of the Armed Forces. Following graduation in 1993, he was promoted to Colonel and assigned as the Deputy Executive Director, Strategic Programming and Contingency Operations at the Defense Logistics Agency. During the fall of 1994, General Lott deployed to Haiti as the Chief of Staff, Joint Logistics Support Command, Multi-National Force. Following this tour, he was assigned as the Executive Assistant to the Deputy Chief of Staff, Installations and Logistics at Headquarters, U.S. Marine Corps while serving concurrently as the Director of Logistics Plans and Policy Analysis.

In June 1996, General Lott reported to 3d Force Service Support Group where he assumed command of 3d Support Battalion and served concurrently as the Commanding Officer, FSSG (Forward). Following command, he reported to Marine Corps Base, Camp Butler as the Assistant Chief of Staff, Marine Corps Community Services. In July 1999, he was promoted to Brigadier General and assumed command of the First Force Service Support Group where he remained until June of 2001. During this same period he also served one rotation as the Commanding General, Coalition/Joint Task Force, Kuwait.

In July 2001, General Lott took command of Marine Corps Materiel Command, Albany, Georgia, later renamed Marine Corps

Logistics Command, and remained there through June of 2003. He was frocked to Major General in September of 2002.

General Lott holds a Bachelor of Science degree from the University of West Florida and a Master of Science degree from the University of Southern California and is a graduate of the National Security Program at Harvard University. His military decorations include the Defense Superior Service Medal, Legion of Merit with gold star, Defense Meritorious Service Medal, Meritorious Service Medal, Navy and Marine Corps Commendation Medal, Army Commendation Medal, Navy and Marine Corps Achievement Medal, Combat Action Ribbon, Joint Meritorious Unit Award, Navy Unit Citation, Meritorious Unit Commendation, and he wears the Navy/Marine Corps Parachutist insignia.

**Ms. Mala Mehrotra**  
**President**  
**Pragati Synergetic Research, Inc.**

Mala Mehrotra is the President/CEO of Pragati Synergetic Research Inc., an 8a certified, small, woman-owned, disadvantaged business specializing in research and development in the areas of ontology analysis, software engineering of intelligent systems, and JAVA-based tool development. Ms. Mehrotra has been performing high-end artificial intelligence research for mainly government clients such as, DARPA, Air Force, Navy, NASA, NSF. for the last 14 years.

Mala Mehrotra has an M. S. degree in Computer Science with concentration in artificial intelligence and parallel computing from the College of William and Mary in VA. In addition she also has an M.S. in Nuclear Physics from Delhi University, India. She has been the main architect of Pragati's flagship product, Multi-ViewPoint



Clustering Analysis (MVP-CA) Tool which partitions large and complex knowledge-based systems into meaningful units for the purpose of analyzing them. MVP-CA tool was used in analyzing IMMACCS, a multi-agent system for command and control, results of which have been presented in the ONR workshop series previously.

Lately Ms. Mehrotra has been the PI on two SBIR projects, one from ONR and another one from NASA Ames. Under the ONR project a prototype OSRT (Ontology Search and Reuse Tool) tool has been built, to address a number of core reuse challenges for ontologies. To date, aligning, mapping and merging ontologies are complicated undertakings that require significant manual effort from their designers. OSRT achieves reuse by enabling users to issue semantically rich queries against large collections of diverse source knowledge bases. It provides the user with multiple views of the query results and a framework to adapt those results for reuse in a target knowledge base under construction. In another separately funded DOD effort Ms. Mehrotra is also trying to address reuse issues in the context of Semantic Web OWL ontologies for CODE (Collaborative Ontology Development Environment) under construction at IHMC (Institute for Human and Machine Cognition).

For the NASA project Ms. Mehrotra is developing an Iterative Ontology Development (IOD) toolkit as a Protege plug-in component. It is a semi-automated information extraction tool that enables analysts to rapidly create structured representations of the information present in natural language text. Pragati's existing clustering technology provides the foundation for IOD's abilities. Clustering brings together fragments of source text that are similar. By viewing the text fragments that cluster together, the user can rapidly identify themes of interest - a

task that would be tedious or impossible if attempting to analyze large corpora by hand.

In her talk Ms. Mehrotra will be addressing the various technical challenges facing us in building and reusing ontologies as well as how do tools, such as OSRT and IOD, try to alleviate some of the problems in this area. In particular she will show how Pragati's tools can help with interoperability issues from diverse information sources such as C2IEDM (Command and Control Information Exchange Data Model), IOM (IMMACCS Object Model) and Cycorp's Command Post of Future knowledge based systems.

### **Colonel Robert C. Morris, Jr. USJFCOM**

Colonel Robert C. Morris, Jr., is an Infantry Officer with extensive Special Operations experience. He served in Korea as a Mechanized Platoon Leader, Company Executive Officer and Scout Platoon Leader. COL Morris served with the 2d Battalion (Ranger), 75th Infantry in Fort Lewis, Washington as a rifle Platoon Leader, Battalion Support Platoon Leader supporting Operation Urgent Fury, and assistant S-4. He was assigned to the 4th Battalion 325th Infantry Airborne Battalion Combat Team (Vicenza, Italy) as the Battalion S-4 then returned with the unit to the 82d Airborne Division as the A Company Commander then the Battalion S-3 (Operations Officer). COL Morris then served three years with the Joint Special Operations Command at Pope Air Force Base, North Carolina as the Logistics Plans and Procurement Officer supporting special operations missions to include Just Cause, Desert Shield/Desert Storm, and classified operations. He was the command's secure environment contracting officer. COL Morris was then assigned to Alaska as the 6th Infantry Division EDRE/Force Modernization Officer,



G-3 Operations Officer, Battalion Executive Officer for the 4th Battalion, 9th Infantry Regiment MANCHUs, and the 1st Brigade, 6th Infantry Division (Light) Executive Officer. During this period COL Morris was personally selected by the Principle Deputy to the Assistant Secretary of Defense For Special Operations/Low Intensity Conflict (SO/LIC) to work at UN Headquarters in Geneva and design the UN Force package concept. The UN High Commissioner for Refugees (Ms Ogata) briefed these, unchanged, to the UN General Assembly where they were approved. COL Morris then became a special project officer for the ASD (SO/LIC). In this capacity he conducted a multi-service functional review of the humanitarian excess program. His efforts supported numerous international humanitarian organizations, programs, and operations to include Rwanda, Eritrea, and former Soviet republics to include Kazakhstan and Turkmenistan. COL Morris was assigned the task to keep the International War Crimes Tribunal for Rwanda and the former Yugoslavia from closing down in Rwanda and accomplished the task. COL Morris commanded the 1st Battalion, 11th Infantry at Fort Benning, followed by service as the Chief, Forced Entry Battle Lab. The VCSA and Cdr, JFCOM created an Army Fellowship in Enroute Mission Planning (EMPRS) he completed in lieu of the Army War College. Following his time in the Fort Benning Battle Lab, COL Morris supported the Army's Unit of Action Maneuver Battle Lab (UAMBL) with primary responsibility to write the Battle Command concept for the Army's Future Force. He is currently the Chief of Space and Decision Superiority for the United States Joint Forces Command J9 (Experimentation) where his primary responsibilities include developing and experimentally validating the Department of Defense's future concepts for Information Operation, Adaptive, Collaborative Planning and Decision-Making as well as Global

Integration across the Inter-Agency Community.

COL Morris has extensive expertise in and strong reputation with international humanitarian organizations. He authored the Program of Instruction (POI) for and co-facilitated the World Food Program's first inter-agency deliberate planning workshop in Burkina Faso, Africa. This workshop marked the first time a United Nations Inter-Agency planning group met with the goal of developing a strategic level plan to react to a complex emergency, effectively moving the organization's emergency response from reactive to pro-active. He helped establish a program at the Army Command and General Staff College (CGSOC) that facilitates collaborative planning exercises between military staffs and Non-governmental organizations. He has a strong relationship with World Food Program, having worked closely with its current logistics director. COL Morris founded Partners International Foundation, a 501(c)(3) Non-Government Organization (NGO). The organization's goals is to make humanitarian aid (both domestically and internationally) more efficient and cost-effective. Partners International Foundation is involved in a myriad of programs both in the United States and abroad. These include support to local community groups, women and children's wellness in Rwanda, a free eye-care clinic in Zimbabwe and a program to provide international humanitarian an human rights speakers to international military officers studying in the United States. Partners International Foundation recently sent an assessment team of former Special Forces Soldiers to Tajikistan and northern Afghanistan as well as provided subject matter experts to Joint and multi-national information operations experimentation. COL Morris serves as an officer in the Foundation apart from his military duties



and operates these programs in his spare time.

COL Morris is the author of several articles on military theory, humanitarian operations, situational awareness, and international aid.

COL Morris has the Bronze Star, the Legion of Merit, the Defense Meritorious Service Medal, five Meritorious Service Medals, three Joint Service Commendation Medals, the Army Commendation Medal, the Joint Service Achievement Medal, the Joint Meritorious Unit Award, five Army Achievement Medals, Southwest Asia Service Medal with two bronze stars, the Armed Forces Expeditionary Medal, the Army Service Ribbon, three awards of the Overseas Ribbon, the Southeast Asia Kuwait Liberation Medal, the Government of Kuwait Liberation Medal, the National Defense Service Medal, the Expert Infantryman's Badge, Master Parachutist Badge, and Ranger Tab.

**Dr. H. Van Dyke Parunak**  
**Chief Scientist**  
**Altarum Corporation**

Dr. H. Van Dyke Parunak ("Van") is Altarum's Chief Scientist, and a Corporate Analyst in the Emerging Markets Group within the Enterprise Solutions Division at Altarum. He leads Altarum's projects in software agents, swarm intelligence, emergent behavior, and nonlinear dynamics, and has been Principal Investigator on numerous DARPA and other projects involving these technologies. Dr. Parunak is the author or co-author of more than 75 technical articles and reports. He is the holder of two patents and ten patents pending in the area of agent technology. His undergraduate degree is in Physics from Princeton University, and he has five graduate degrees, including a Ph.D. from Harvard University.

**Dr. Jens G. Pohl**  
**Executive Director, Collaborative**  
**Agent Design Research Center, and**  
**Graduate Coordinator, Architecture**  
**Department, Cal Poly, San Luis Obispo,**  
**California**

Dr. Jens Pohl holds the positions of Professor of Architecture, Executive Director of the Collaborative Agent Design Research Center (CADRC), and Post-Graduate Studies Coordinator, in the College of Architecture and Environmental Design, California Polytechnic State University (Cal Poly), San Luis Obispo, California, US.

Professor Pohl received his formal education in Australia with degrees in Architecture and Architectural Science: B.Arch. (University of Melbourne, 1965) M.Bdg.Sc. and Ph.D. (University of Sydney 1967 and 1970). He taught in the School of Building at the University of New South Wales in Sydney, Australia, until the end of 1972 and then left for the US where he was appointed to the position of Professor of Architecture at Cal Poly. Following several years of research and consulting activities in the areas of building support services and information systems, Dr. Pohl's research focus today lies in the application of distributed artificial intelligence methodologies to decision-support systems in engineering design, logistical planning, and military command and control.

Under his direction the Collaborative Agent Design Research Center at Cal Poly has over the past 11 years developed and implemented a number of distributed computing applications in which multiple computer-based and human agents collaborate in the solution of complex problems. Foremost among these are the ICDM (Integrated Cooperative Decision Model) and TIRAC (Toolkit for Information Representation and Agent Collaboration) frameworks which have been applied to



engineering design (industry sponsorship: ICADS - 1986 to 1991), energy conservation (US Dept. of Energy sponsorship: AEDOT - 1992 to 1993), logistical planning (US Army (MTMC) sponsorship: ICODES - 1993 to present), military mission planning (US Marine Corps (MCWL) sponsorship: FEAT, FEAT4 and IMMACCS - 1994 to present), and facilities management (US Navy (ONR) sponsorship: CIAT, SEAWAY, and LOGGY - 1996 to present).

The Integrated Marine Multi-Agent Command and Control System (IMMACCS) was successfully field-tested as the command and control system of record during the Urban Warrior Advanced Warfighting Exercise (AWE) conducted by the Marine Corps Warfighting Laboratory (MCWL) in Central California (Monterey and Oakland) during the period March 11 to 18, 1999, during a live fire Limited Objectives Exercise (LOE) held at Twentynine Palms, California, in March 2000, and during the recent Kernal Blitz Exercise held on the West Coast in June 2001. The Integrated Computerized Deployment System (ICODES) was designated by the US Department of Defense as the 'migration system' for ship loading in July 1995. ICODES V.3 was released to the US Army in 1997 and ICODES V.5 is being released to the US Marine Corps and US Navy this year (2002).

Dr. Pohl is the author of two patents (US), several books, and more than 80 research papers. He is a Fellow of the International Institute for Advanced Studies in Systems Research and Cybernetics, and was awarded an honorary doctorate by the Institute in August, 1998, during the InterSymp-98 conference held in Baden-Baden, Germany. Professor Pohl is a Fellow of the Royal Australian Institute of Architects, a Fellow of the Australian Institute of Building, a Member of the

American Institute of Constructors, and a member of IEEE.

## **Dr. Conrad W. Strack**

Senior Systems Analyst, CSCI

Conrad W. Strack, Ph.D. Senior Systems Analyst at CSCI, responsible for developing quantitative estimates of cost, performance, and benefits for the definition, design, and evaluation of military and intelligence systems.

Specific experience includes:

- **network-centric interoperability costs** Estimated life-cycle costs of achieving interoperability for a layered family of defense platforms using JDN (Link 16), CEC, and/or JCTN for legacy software, open architecture, or common host versions of Aegis, LH, CV, E-2C, TPS-59, AWACS, Patriot, THAAD, JLENS, MEADS, Sentinel, JSTARS, Predator, Global Hawk, SBIRS, TPS-75 with EMT, F-16 block 50, F-18 E/F, JSF, F-22, Navy Area, and Navy Theaterwide.
- **network-centric C<sup>3</sup> effectiveness** Designed and directed Joint Service experiments at the Naval Postgraduate School to estimate value added by C<sup>3</sup> network attributes - connectivity, centrality, organization, and coordination - to military force effectiveness.
- **C<sup>3</sup> performance evaluation** Directed support of JCS C<sup>3</sup> Global Assessment, producing the *JCS C<sup>3</sup> Master Plan*, *USSOUTHCOM C<sup>3</sup> Master Plan*, *JCS C<sup>3</sup> Architecture Annex*, *USTRANSCOM PAR Annex*, and the *USSPACECOM PAR Annex*.
- **interoperability countermeasures** Devised the first complete system-level defense suppression attacks and BM/C<sup>3</sup> countermeasures for Brilliant Pebbles and Ground Based Interceptor layered



defense architectures. This included target selection, launch and penetration strategies, and integrated countermeasures suites.

- **specific interoperability cost estimates**

CEC, JCTN, Gateway, Minimum Mix, MMAA, National Cruise Missile Defense, TBMD Using Link 16, JTAMD Master Plan, JMAA, JTAMD EXCOM, JDEP, RAMOS, NATO TAMD, SIAP Block 1, BMDSAS, Common Host Initiative.

**Dr. Andreas Tolk**  
**Virginia Modeling Analysis and Simulation Center, Old Dominion University**

Dr. Andreas Tolk is Senior Research Scientist at the Virginia Modeling Analysis and Simulation Center (VMASC) of the Old Dominion University (ODU) of Norfolk, Virginia. He has over 14 years of international experience in the field of Applied Military Operations Research and Modeling and Simulation of and for Command and Control Systems. He participated in several projects of the NATO Research & Technology Organization as a subject matter expert for M&S and Command and Control. In addition to his research work, he gives lectures in the M&S program of ODU. His domain of expertise is the integration of M&S functionality into related application domains, such as C4ISR or Service-oriented Architectures, in particular based on open standards.

**Mr. Peter M. Trask**  
**The Johns Hopkins University, Applied Physics Laboratory**

Peter M. Trask is the Branch Supervisor for Strategic and National Command and Control

at The Johns Hopkins University, Applied Physics Laboratory (JHU/APL), in Laurel, Maryland. He is responsible for JHU/APL programs in global information integration and decision-making, focusing on the DoD's transition to net-centric operations and warfare.

From 1997 through March 2004, Mr. Trask was a member of the federal government's Senior Executive Service (SES). He served as Product Area Director for Undersea Warfare (USW) Weapons and Vehicle Systems at the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island. He was responsible for programs across the Naval Sea Systems Command (NAVSEA) warfare centers in torpedoes, unmanned undersea vehicles, platform defensive systems, USW launchers, submarine tactical missile systems integration, and USW unmanned surface vehicles. Prior to that, he was Head of the Submarine Electromagnetic Systems Department, where he had responsibility for NUWC's work in submarine communications, electronic surveillance, information operations, and imaging systems and served as lead for NUWC's FORCEnet initiatives. He was a member of the Navy's acquisition professional community and was NAVSEA's technical authority warrant holder for submarine imaging and electronic warfare systems.

From 1995 to 1997, Mr. Trask was a member of the senior professional staff at JHU/APL, where he was responsible for development and transition of submarine information management and communications programs. From 1987 to 1989, he served as Science Advisor to the Commander, Submarine Force, U.S. Atlantic Fleet in Norfolk, Virginia, where he was responsible for introducing several quick-reaction capabilities for submarines in response to urgent operational requirements. Early in his career, Mr. Trask performed RDT&E of submarine communications antennas and submarine ESM systems at



NUWC's Detachment in New London, Connecticut. He later served in several management positions at NUWC, including program manager for Submarine Electronic Warfare Systems and Periscopes, and Head of the Communications Systems Division.

Mr. Trask received a Bachelor of Science degree in electrical engineering in 1971 from Northeastern University where he was elected to the Tau Beta Pi and Eta Kappa Nu engineering honor societies. In 1976, he received a Master of Science degree in electrical engineering from the University of Connecticut. In 1984, he was selected as a Fellow at the Sloan School of Management at the Massachusetts Institute of Technology, where he received a Master of Science degree in management in 1985. He has received the National Defense Industrial Association Bronze Medal, Navy Superior Civilian Service Award, and the Navy's Science Advisor of the Year award. He has been a lecturer in the MIT Professional Summer Program and has presented at numerous professional conferences.

**Mr. Paul Ulrich**  
**Shonborn Becker Systems, Inc.**

Mr. Paul Ulrich is a Senior Technical Advisor to the Project Manager Ground Combat Command & Control (PM GCC2) and the Product Manager for the Army's Maneuver Control System (PM MCS), where he works on a wide range of advanced concepts. He serves as the US Head of Delegation to the Multilateral Interoperability Programme (MIP), a multinational interoperability effort to specify how to exchange data between C2 Information Systems in a coalition environment. He has served as the Chairman of the MIP Steering Group (MSG) as well as Chairman of the MIP Programme Management Group (PMG) during MIP Block 1 program efforts culminating in an Integrated Operational Test & Evaluation in September

2003 in Ede, NL. He also participates in the Army Battle Command System (ABCS) efforts to define and implement Intra-Army, Joint Service Interoperability as well as Coalition Interoperability standards and specifications. Prior to his retirement from government service in 2001, he served as Deputy Project Manager for Army Tactical Command & Control Systems and Deputy Product Manager for the Maneuver Control System as well as numerous other positions in C2 system development. He is a graduate of Newark College of Engineering (1968 & 1973).

**Dr. Steven Wartik**  
**Institute for Defense Analyses**

Steven Wartik has been a Research Staff Member at the Institute for Defense Analyses since 1997, where he has studied C4I specification, design, and implementation. He participated in the development of the C4ISR Reference Object Model, and has contributed to the system architecture of the Global Combat Support System and JOPES-2000. Recently he has been studying knowledge bases and their proper role in the DoD infrastructure.

Dr. Wartik received his Ph.D. in Computer Science from the University of California at Santa Barbara in 1983. He has published over 20 papers in C4I/M&S interoperability, software reuse, software configuration management, software engineering education, and information retrieval.

**Mr. David S. Waxman**  
**Executive Architect**  
**Homeland Security**  
**IBM Software Group**

David S. Waxman is an executive architect within IBM's Industry Solutions Development Group. As an expert in the design and delivery of cost-effective, high



performance information technology infrastructures and applications, he was selected from industry to provide strategic planning and tactical responsibility for technological implementations within the Homeland Security arena. David is also a team leader of IBM's Corporate Technology Assessment Team for Homeland Security. In this role he is helping to shape the high level strategy and to outline the corresponding technical opportunities for IBM.

**Col. Anthony Wood (USMC Ret.)**  
**Vice President, CDM Technologies,**  
**Inc., San Luis Obispo, California**

Colonel Anthony A. Wood (USMC Ret.) joined CDM Technologies in 1998 after 31 years in the Marine Corps. In 1995, he created the Marine Corps Warfighting Laboratory and served as its first director from 1995 to 1998. Colonel Wood also holds the position of Director of Applied Research with the Collaborative Agent Design Research Center at California Polytechnic State University.

In the course of his service, he has been responsible for a number of unique conceptual and practical contributions to joint warfare, naval expeditionary warfare, and our military posture in the Pacific. In 1968, he served his first tour in Vietnam as a platoon commander and then advisor to the Korean Marine Corps Blue Dragon Brigade. In his second tour in Vietnam in 1974-75, Captain Wood commanded a joint-contingent executing clandestine mission in Laos, Cambodia, and Vietnam. In January 1975, Maj General Homer Smith, USA, the Defense Attache in Saigon, had him transferred to the Defense Attache Office, where he was directed to secretly develop a plan for the evacuation of Saigon. Capt. Wood then executed that plan in April of 1975. Col. Wood has since served

in a succession of infantry and reconnaissance command billets and several staff assignments.

As the principal author of the US Navy and Marine Corps "Maritime Prepositioning Concept", he developed a detailed concept and then supervised the implementation of a national strategic response capability based on forward positioning three squadrons of specially configured climate controlled ships. Each of these squadrons contained prepackaged supplies and equipment sufficient to support a force of 15,000 Marines for thirty days. While serving as Chief of Staff Marine Forces Pacific, Colonel Wood was dispatched to Russia in 1993. There, over a two-week period of negotiations, he successfully concluded a major tension reduction agreement and multi-year exercise program with the Russian General Staff, the Commander Russian Pacific Fleet in Vladivostok, and the Commander Russian Far East Military District in Khabarovsk. Designed to relax tensions and reduce the risk of nuclear incidents in the Pacific Theater, the agreement has since been extended.

Colonel Wood's last billet was as founding Director and Commanding Officer of the Marine Corps Warfighting Laboratory from 1995-1998. Unique in its concept-based approach as well as its projection of a very different and non-traditional post cold war future, the laboratory spear headed Marine experiments to recast military capabilities in a mold appropriate to emerging future requirements.



# Interoperability and the Need for Intelligent Software

**Jens Pohl, Ph.D.**

Executive Director

Collaborative Agent Design Research Center (CADRC)

California Polytechnic State University (Cal Poly)

San Luis Obispo, California

In my introduction to this year's conference I will address six questions that I believe come to the core of our conference theme of *interoperability*. Do we human beings resist change? Is it in fact a human problem and not a technical problem that we are dealing with? Can non-human intelligence exist? Do we even have a need for intelligent software? How did software, particularly intelligent software (i.e., if we accept that there is such a thing) evolve over the past several decades, and what is all this talk about a *Semantic Web* environment? And, finally, what does the future hold in the next five to ten years?

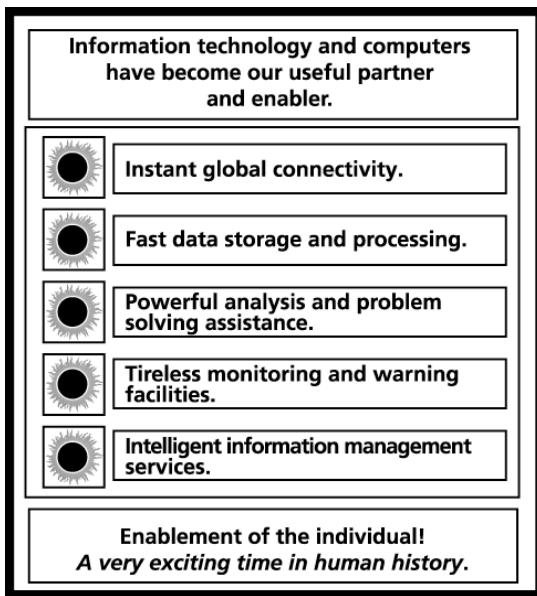


Fig.1: "...it was the best of times..."

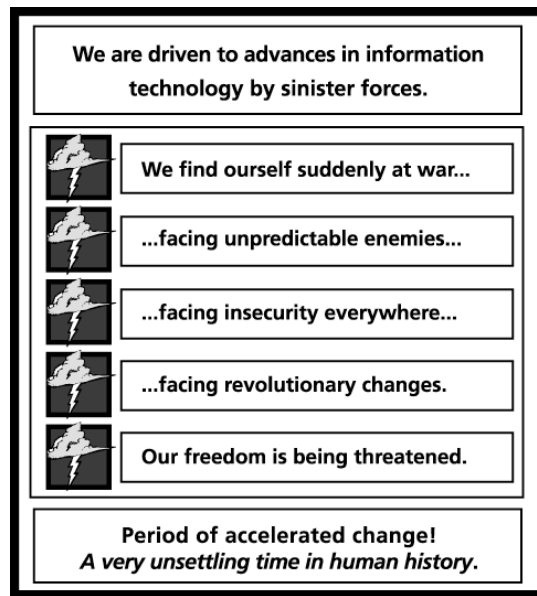


Fig.2: "...it was the worst of times..."

I would like to start by paraphrasing one of my favorite authors, Charles Dickens. Many of you will recall that in The Tale of Two Cities, he started off the entire book with a long paragraph that began with the words: "...it was the best of times, it was the worst of times..." These are words that I believe apply very much today. We are in the best of times, because information technology and computers have become a useful partner and enabler that bring us very powerful capabilities. To mention only a few (Fig.1), we have: global connectivity; very fast data storage and processing devices; powerful analysis and problem solving assistance; tireless monitoring and warning facilities; and, intelligent information management services. All of these capabilities greatly enable the individual. Today a single person is able to accomplish what entire organizations had difficulty



accomplishing 20 to 30 years ago. Surely, all of this adds up to a very exciting time in human history.

But surely, we are also experiencing the worst of times (Fig.2). We are driven to information system advances by very sinister forces. Suddenly, we find ourselves at war, facing unpredictable enemies, insecurity everywhere, and revolutionary change. Our very freedom is being threatened. We are in a period of accelerated change and such periods bring about a great deal of tension. Therefore, we are also experiencing a very unsettling time in human history. What are some of these changes, and they are indeed profound changes. We are transitioning from a society that was largely governed by a sense of singularity to a society that has to increasingly deal with plurality. Most everything that we human beings have designed and produced in the past has been mechanical in nature. Mechanical systems are sequential systems. Organic systems, information systems, are pluralistic systems. They operate in parallel. So we are moving from a world that used to be paced by sequential actions to a world in which a great deal of parallelism exists.

### **Human Resistance to Change**

We used to learn that the most efficient way of providing services is to centralize those services. Today we know that centralized facilities are a serious liability, because they present a tempting and relatively convenient target to terrorist. It has become generally acknowledged that we need to distribute our essential facilities and services in a networked manner with a high degree of redundancy. We are learning to move from a hierarchical organizational structure in management to a very flat organizational structure. This change in management philosophy and style is further evidence of the enablement of the individual. Organizations are becoming increasingly interested in knowledge management, as they begin to realize the value of every person in the organization. Particularly, our military forces are moving from a centralized command and control environment to distributed command and coordination with power at the edge.

There is another change that is much more subtle, yet very important. Over the past century mathematicians have made great strides in providing us with powerful tools for categorizing, analyzing and identifying patterns in large sets of data. I am referring to the field of statistics, which is largely based on norms (i.e., on satisfying the majority of any data set or population). Means, standard deviations and confidence limits, regardless of how accurately we can calculate them mathematically, do not give us much protection from asymmetric threats. Today, the exceptions are becoming more and more important. That is a major paradigm shift. We can no longer consider the norms alone, but must increasingly look at the exceptions. Yet, we have few if any tools to help us with the assessment of exceptions. Whether a person is going to become a suicide bomber is not something that you are going to be able to predict statistically. The factors governing such behavior tend to be governed by exceptional circumstances.

We human beings have an innate aversion to change. Why is this so? The reason is that we are in every respect experience-based. Our confidence or comfort level comes from our experience. As soon as we move out of our experience base we move into the unknown and we move into a risk area. Physiologically, we are a product of biological evolution. Our brain is composed of different parts, some of which are deeply rooted in



the evolution of our earliest ancestors. We adapt continuously and gain in experience as we react to the stimulation of our environment. Psychologically, we are subject to often uncontrolled emotional forces. Our confidence is fragile. We are fearful of the unknown and intellectually, as I mentioned previously, we are almost entirely experience-based. We rely heavily upon intuition and our forecasts of the future are usually wrong.

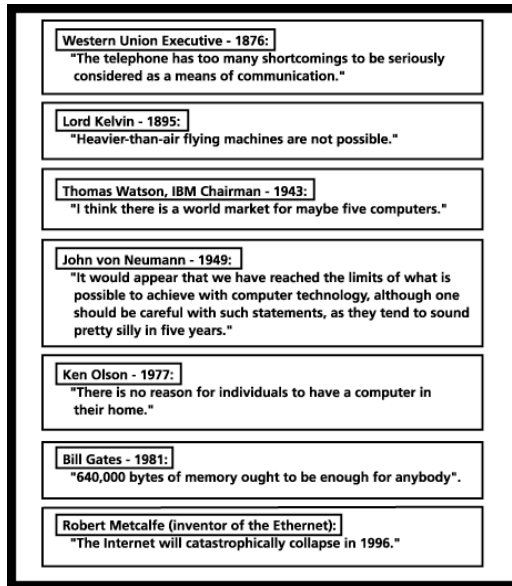


Fig.3: Forecasting the future

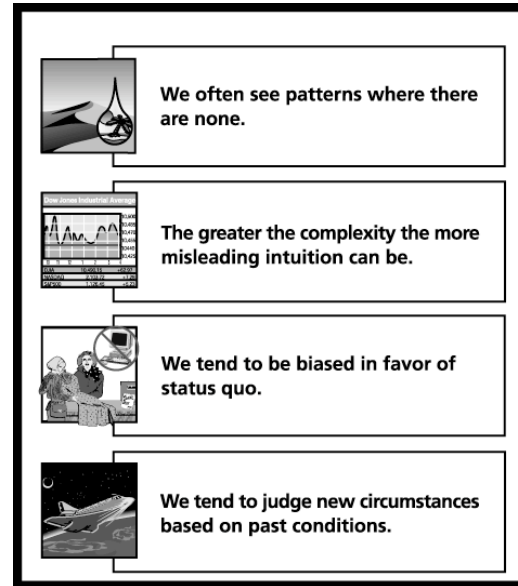


Fig.4: The frailties of human intuition

The fact is that we are involved in changes that constitute a paradigm shift and are the cause of a great deal of tension. In talking about forecasting the future, not long ago in 1943 (Fig.3), we had the Chairman of IBM Corporation, Thomas Watson, saying: "...I think there is a world market for maybe five computers." In 1949, John van Neumann said with a little less certainty: "...It would appear that we have reached the limits with what it is possible to achieve with computer technology, although one should be careful with such statements as they tend to sound pretty silly in five years." Ken Olson, in 1977 prophesized: "...There is no reason for individuals to have a computer in their home." In 1981, Bill Gates suggested that: "...640K bytes of memory ought to be enough for anybody." And finally, Robert Metcalf the inventor of the Ethernet warned us that: "...The Internet will catastrophically collapse in 1996." So, we don't do well looking into the future for the simple reason that we have no experience to base that future on.

In terms of human cognition and intuition (Fig.4), the reality is that we often see patterns where there are none. The greater the complexity the more misleading our intuition tends to be. More often than not we are biased in favor of the status quo, because that is our experience and we tend to judge new circumstances based on past conditions.

## Human and Non-Human Intelligence

Can there be non-human intelligence? Can the computer help us in our decision making endeavors in an intelligent partnership role? The answer to this question depends very much on our viewpoint or premises. Human beings tend to be rather self-centered. We believe that everything in our environment revolves around us. Therefore, from our



human point of view, we are easily persuaded that intelligence is something that belongs innately to us. This school of thought argues that computers are electronic machines that do not and will never display truly intelligent capabilities (Fig.5). Certainly, I would agree that computers are unlikely to gain human intelligence in the near future. Several strong arguments are advanced by that school (Dreyfuss 1979 and 1997, Dreyfuss and Dreyfuss 1986, Lucas 1961, Searle 1980 and 1992). First, it is argued that humans are situated in the world by virtue of their bodies and that human level intelligence is impossible without a body. The second argument points out that symbolic reasoning and logic are not the basis of human intelligence. Human behavior is not rational and thinking does not necessarily follow rules. Third, it is argued that the world can be neither analyzed nor divided into independent logical elements. It therefore follows that the formalization and simulation of intelligent behavior is not possible. The final summary argument of that school of thought is that for these stated reasons intelligence is the province of living creatures, specifically human beings.

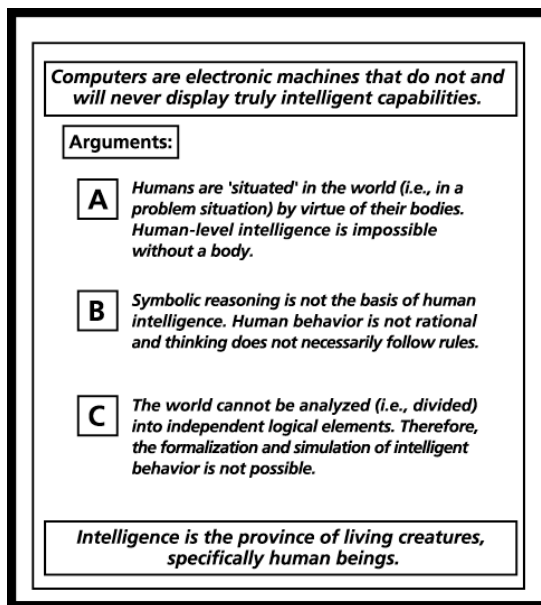


Fig.5: The human view of intelligence

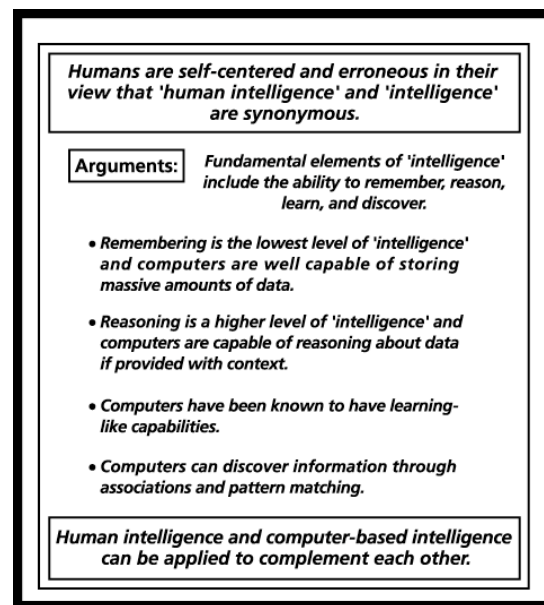


Fig.6: A general view of intelligence

A more general view of intelligence would hold that there are some fundamental elements of intelligence such as the ability to remember, to reason, to learn, and to discover or create (Fig.6). From that point of view, *remembering* as the lowest level of intelligence can certainly be accomplished by computers. In fact, one could argue that the storage capacity of computers exceeds the long term memory capacity of human beings. *Reasoning* is a higher level of intelligence and computers are capable of reasoning as long as they have some context within which to reason. Computers cannot reason about data without context. I will come back to that issue in a few minutes. Also, computers have been shown to have some learning capabilities, and computers can even discover information through association and pattern matching. The concept of discovery is a core capability on which many of the expected capabilities of the Global Information Grid (GIG) will depend. That is, the notion that a software application will be able to automatically discover resources.



## **The Need for Intelligent Software**

Whether there is a need for intelligent software, is the next obvious question? Until about four years ago, whenever I made a presentation like this there would always be a number of people who would come to me afterwards and say: "...well this all sounds very feasible, but do we need computer intelligence? Surely, we human beings are the ones who have intelligence and we will be able to do the necessary reasoning and interpretation of data." Today, I rarely hear those arguments, because we are beginning to realize that we are inundated with data, and we desperately need help.

There are essentially two compelling reasons why computer software must increasingly incorporate more and more 'intelligent' capabilities. The first reason relates to the current data-processing bottleneck. Advancements in computer technology over the past several decades have made it possible to store vast amounts of data in electronic form. Based on past manual information handling practices and implicit acceptance of the principle that the interpretation of data into information and knowledge is the responsibility of the human operators of the computer-based data storage devices, emphasis was placed on storage efficiency rather than processing effectiveness. Typically, data file and database management methodologies focused on the storage, retrieval and manipulation of data transactions, rather than the *context* within which the collected data would later become useful in planning, monitoring, assessment, and decision-making tasks.

The second reason is somewhat different in nature. It relates to the complexity of networked computer and communication systems, and the increased reliance of organizations on the reliability of such information technology environments as the key enabler of their effectiveness, profitability and continued existence.

### ***The Data-Processing Bottleneck***

This requires further explanation, as a fundamental issue and one of the primary forces driving the evolution of software intelligence. The design of any information system architecture must be based on the obvious truth that the only meaningful reason for capturing and storing data is to utilize them in some planning or decision-making process. However for data to be useful for planners and decision makers they have to be understood in context. In other words, data are just numbers and words that become meaningful only when they are viewed within a situational framework. This framework is typically defined by associations that relate data items to each other and peripheral factors, which influence the meaning of the data in a particular situation. Succinctly stated, numbers and words (i.e., data) found within a rich set of relationships become information, which provides the necessary context for interpreting the meaning of the data, the recognition of patterns, and the formulation of rules, commonly referred to as knowledge.

The larger an organization the more data it generates itself and captures from external sources. With the availability of powerful computer hardware and database management systems the ability of organizations to store and order these data in some purposeful manner has dramatically increased. However, at the same time, the expectations and need to utilize the stored data in monitoring, planning and time-critical decision-making tasks has become a major human



resource intensive preoccupation. In many respects this data-centric focus has become a bottleneck that inhibits the ability of the organization to efficiently and effectively accomplish its mission.

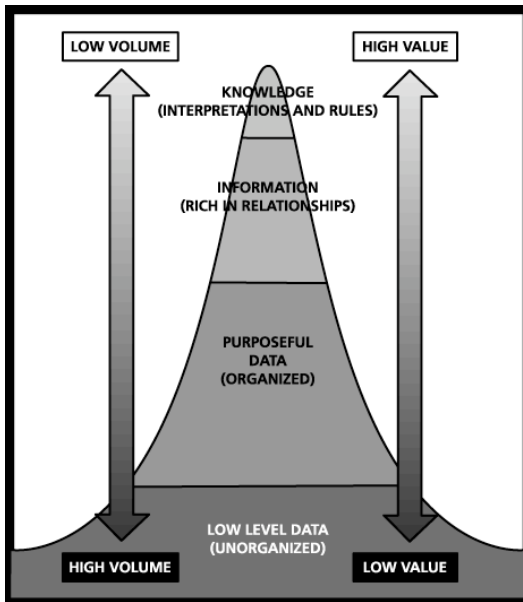


Fig.7: From data to knowledge

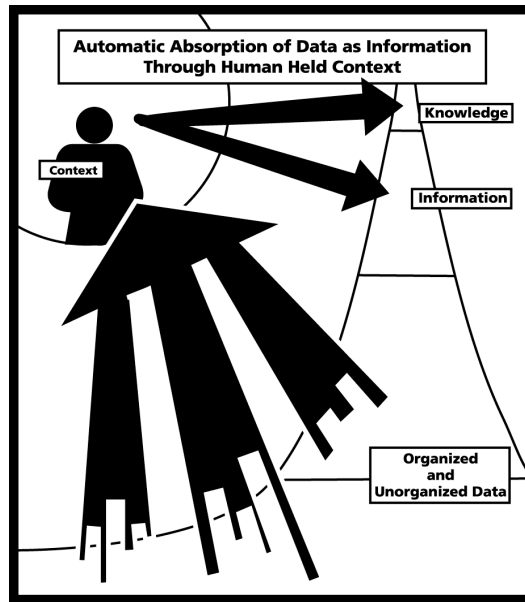


Fig.8: Human interpretation of data

The reasons for this bottleneck are twofold. First, large organizations are forced to focus their attention and efforts on the almost overwhelming tasks involved in converting unordered data into purposefully ordered data (Fig.7). This involves, in particular, the establishment of gateways to a large number of heterogeneous data sources, the validation and integration of these sources, the standardization of nomenclatures, and the collection of data elements into logical data models. Second, with the almost exclusive emphasis on the slicing and dicing of data, rather than the capture and preservation of relationships, the interpretation of the massive and continuously increasing volume of data is left to the users of the data (Fig.8). The experience and knowledge stored in the human cognitive system serves as the necessary context for the interpretation and utilization of the ordered data in monitoring, planning and decision-making processes. However, the burden imposed on the human user of having to interpret large amounts of data at the lowest levels of context has resulted in a wasteful and often ineffective application of valuable and scarce human resources. In particular, it often leads to late or non-recognition of patterns, overlooked consequences, missed opportunities, incomplete and inaccurate assessments, inability to respond in a timely manner, marginal decisions, and unnecessary human burn-out. These are symptoms of an incomplete information management environment. An environment that relies entirely on the capture of data and the ability of its human users to add the relationships to convert the data into information and thereby provide the context that is required for all effective planning and decision-making endeavors.



A more complete information management environment considers data to be the bottom layer of a three-layer architecture, namely:

A **Data Layer** that integrates heterogeneous data sources into accessible and purposefully ordered data. It typically includes a wide variety of repositories ranging from simple textual files to databases, Data Portals, Data Warehouses, and Data Marts.

A **Mediation Layer** that defines the structure of the data sources (i.e., logical data models), data transfer formats, and data transformation rules. The two principal purposes of the Mediation Layer are to facilitate the automated discovery of data and to support the mapping of data to information. In other words, the Mediation Layer serves as a registry for all definitions, schemas, protocols, conventions, and rules that are required to recognize data within the appropriate context. The Mediation Layer also serves as a translation facility for bridging between data with structural relationships (e.g., based on a logical data model) and information that is rich in contextual relationships.

An **Information Layer** that consists of many functionally oriented planning and decision-assistance software applications. Typically, these applications are based on internal information models (i.e., object models or ontologies) that are virtual representations of particular portions of the real world context. By providing context, the internal information model of each application is able to support the automated reasoning capabilities of rule-based software agents.

In such a three-layered information management environment the Mediation Layer continuously populates the information models of the applications in the Information Layer with the data changes that are fed to it by the Data Layer. This in turn automatically triggers the reasoning capabilities of the software agents. The collaboration of these agents with each other and the human users contributes a powerful, near real-time, adaptive decision-support environment. The agents can be looked upon as intelligent, dynamic tools that continuously monitor changes in the real world. They utilize their reasoning and computational capabilities to generate and evaluate courses of action in response to both real world events and user interactions. As a result the human user is relieved of many of the lower level filtering, analysis, and reasoning tasks that are a necessary part of any useful planning and problem solving process. However, just as importantly, the software agents continuously and tirelessly monitor the real world execution environment for changes and events that may impact current or projected plans.

### ***The Increasing Complexity of Information Systems***

The economic impact on an organization that is required to manually coordinate and maintain hundreds of interfaces between data-processing systems and applications that have no ‘understanding’ of the data that they are required to exchange, is enormous. Ensuing costs are not only related to the requirement for human resources and technical maintenance (normally contracted services), but



also to the indirect consequences of an information systems environment that has hundreds of potential failure points.

Recent studies conducted by IBM Corporation and others have highlighted the need for autonomic computing as the organizational expectations and dependence on information services leads to more and more complex networked computer solutions (Ganek and Corbi 2003). In the commercial sector “...it is now estimated that at least one-third of an organization’s IT (Information Technology) budget is spent on preventing or recovering from crashes” (Patterson et al. 2002). Simply stated (Fig.9), autonomic computing utilizes the ‘understanding’ that can be represented within an information-centric software environment to allow systems to automatically: (1) reconfigure themselves under dynamically changing conditions; (2) discover, diagnose, and react to disruptions; (3) maximize resource utilization to meet end-user needs and system loads; and, (4) anticipate, detect, identify, and protect themselves from external and internal attacks.

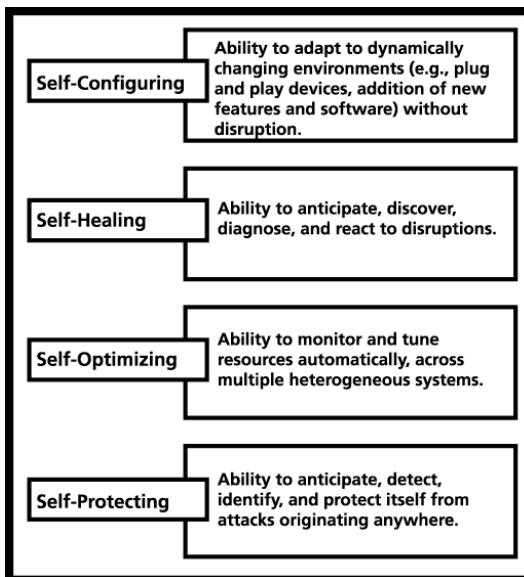


Fig.9: Desirable autonomic capabilities

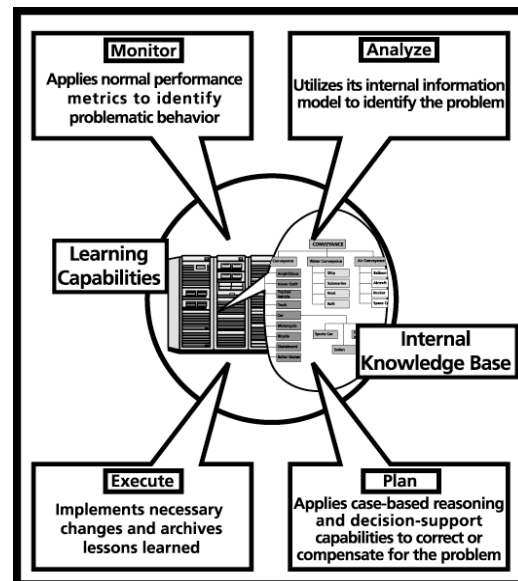


Fig.10: Autonomic self-healing facilities

These same studies have found that more than 40% of computer system disruptions and failures are due to human error. However, the root cause of these human errors was not found to be lack of training, but system complexity. When we consider that computer ‘downtime’ due to security breaches and recovery actions can cost as much as (US)\$2 million per hour for banks and brokerage firms, the need for computer-based systems that are capable of controlling themselves (i.e., have autonomic capabilities) assumes critical importance.

A core requirement of autonomic computing is the ability of a computer-based information system to recover from conditions that already have caused or will likely cause some part(s) of the system to fail. As shown in Fig.10, this kind of self-healing capability requires a system to continuously monitor itself so that it can identify, analyze and take mitigating actions, preferably before the disruption takes place. In addition, the system should be able to learn from its own



experience by maintaining a knowledge base of past conditions that have caused malfunctions and the corrective measures that were taken.

In summary, the continued expansion of networks (e.g., the Internet and its successors) will provide seamless connectivity among countless nodes on a global scale. While the collection of data has already increased enormously over the past decade, the availability of such a global network is likely to increase the volume of data by several orders of magnitude. Such a volume of raw data is likely to choke the global network regardless of any advances in communication and computer hardware technology. To overcome this very real problem there is a need to collect data in context so that only the data that are relevant and useful are collected and transmitted within the networked environment. Most (if not all) of the necessary filtering must be achieved automatically for at least three reasons. First, organizations cannot afford to utilize human resources for repetitive tasks that are tedious and require few human intellectual skills. Second, even if an organization could afford to waste its human resources in this manner it would soon exhaust its resources under an ever-increasing data load. Third, it does not make sense for an organization to 'burn-out' its skilled human resources on low-level tasks and then not have them available for the higher-level exploitation of the information and knowledge generated by the lower level tasks.

Finally, the increased reliance on computer-based information systems mandates a level of reliability and security that cannot be achieved through manual means alone. The alternative, an autonomic computing capability, requires the software that controls the operation of the system to have some understanding of system components and their interaction. In other words, autonomic computing software demands a similar internal information-centric representation of context that is required in support of the knowledge management activities in an organization. In both cases the availability of data in context is a prerequisite for the reasoning capabilities of software agents (i.e., the automatic interpretation of information by the computer).

### **A Framework for Assessing Software Capabilities**

Just like the initial conception and implementation of computing devices was driven by the human desire to overcome the limitations of manual calculation methods, the advancements in computing technology during the past 50 years have been driven by the desire to extend the usefulness of computer-based systems into virtually every human activity. It is not surprising that after several orders of magnitude increases in hardware performance (i.e., computational speed and data storage capacity (Pohl 1998)) had been achieved, attention would gradually shift from hardware to software.

Increasingly software is being recognized as the vehicle for computers to take over tasks that cannot be completely predefined at the time the software is developed. The impetus for this desire to elevate computers beyond data-processing, visualization and predefined problem-solving capabilities, is the need for organizations and individuals to be able to respond more quickly to changes in their environment. Computer software that has no 'understanding' of the data that it is processing must be designed to execute predefined actions in a predetermined manner. Such software performs very well in all cases where it is applied under its specified design conditions and performs increasingly poorly, if at



all, depending on how much the real world conditions vary from those design specifications. Instead, what is needed is software that incorporates tools, which can autonomously adapt to changes in the application environment.

Adaptable software presupposes the ability to perform some degree of automated reasoning. However, the critical prerequisite for reasoning is the situational context within which the reasoning activity is framed. It is therefore not surprising that the evolution of computer software in recent years has been largely preoccupied with the relationship between the computational capabilities and the representation of the data that feed these capabilities. One could argue that the historical path from unconnected atomic data elements, to data structures, relational databases, data objects, object-oriented databases, object models, and ontologies, has been driven by the desire to provide information context in support of automated reasoning capabilities.

However, to be able to present a true historical perspective of the evolution of software it is necessary to take into account a more comprehensive set of criteria. In fact, there are several factors that have in the past and are continuing to contribute to the evolution of intelligent software. This section will attempt to establish a set of categorization criteria to serve as a framework for tracing the capabilities of software. Since these capabilities are closely related to the design and implementation of the computer-based environment within which the software is required to operate, the proposed framework will utilize **system architecture** as a yardstick and milestone component. The following eight system architectures have been selected to serve as milestones for the assessment of software capabilities:

- ***Single data-centric applications*** that operate in a stand-alone mode and receive data from user interaction and other closely coupled sources (e.g., data files and dedicated databases).
- ***Confederation of linked data-centric applications*** with application-to-application data bridges. Also described as ‘stove-pipe’ systems because the system components are essentially hardwired to only work together within their confederation.
- ***Shared database systems*** consisting of multiple data-centric applications that are able to share data between themselves and a common repository, through application-to-database bridges. The repository may be either a single database or a distributed database facility.
- ***Distributed expert systems*** with dedicated knowledge bases (i.e., rules) and a single shared fact list (i.e., data).
- ***Distributed static information-based applications*** with collaborative agents, capable of exchanging data with external data-centric applications.
- ***Distributed static information-sharing applications*** with collaborative agents, capable of interoperating at the ‘information’ level with other ontology-based applications and capable of exchanging data with external data-centric applications.
- ***Distributed extensible information-sharing applications*** with collaborative agents, capable of interoperating at the ‘information’ level with other



ontology-based applications and capable of extending their internal information representation (i.e., ontology) during execution.

- **Semantic Web services** capable of discovering other Web services and dynamically configuring themselves into distributed systems on an as-needed basis.

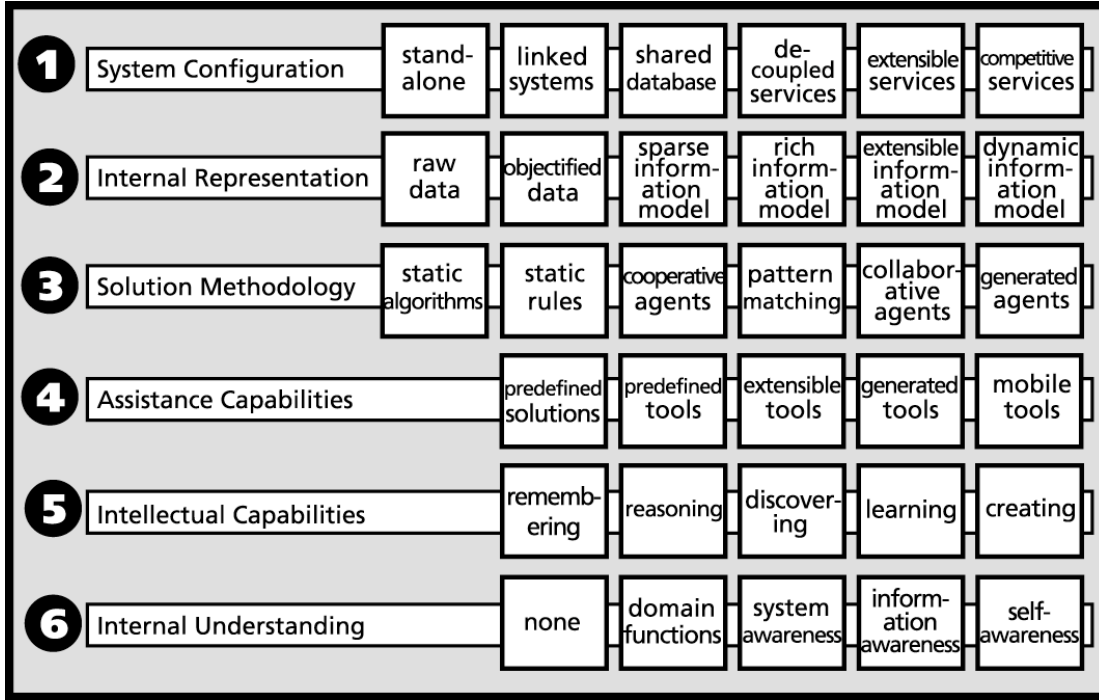


Fig.11: Software characterization categories and their capability criteria

The software capabilities that have been in the past or are still today prevalently applied in each of these system architectures are characterized within six capability groups as shown in Fig.11. While the first of these groups (i.e., Group (1) *System Configuration*) is intended to describe principal architectural features, the other five groups are focused on the degree to which the software is capable of representing and processing data with or without context in partnership with the human user. Fundamental in this respect is Group (2) *Internal Representation*. The manner in which an application represents the data that it is intended to manipulate essentially determines the level of software intelligence that the application is capable of supporting. Group (2) differentiates among applications that represent data without context (i.e., ‘raw data’ and ‘objectified data’), applications that provide context in the form of a static information model (i.e., ‘sparse information model’ and ‘rich information model’) and applications with information models that are extensible during execution (i.e., ‘extensible information model’ and ‘dynamic information model’). The remaining four groups address the general solution methodology available to the application, its decision-support capabilities, and the level of internal ‘understanding’ of its capabilities, activities and intrinsic nature. The divisions within each of the groups will be defined in more detail during the discussion of each of the eight system architectures.



The first system architecture for discussion (Fig.12) is representative of the typical early computer applications, namely a stand-alone application that receives all of its data from the user and/or data sources that are considered to be part of the application. Whether or not the data are treated as discrete elements or objects, the *Internal Representation* includes only a very limited set of relationships and therefore lacks context. Under these circumstances the *Assistance Capabilities* are limited to predefined solutions utilizing static algorithms, no internal understanding can be provided by the representation of data without relationships, and the *Intellectual Capabilities* of the software are restricted to ‘remembering’ since the data are stored in the computer. The second system architecture (Fig.13) adds data bridges between several data-centric applications. Each bridge is simply an application-to-application mapping of the data format of one application to the other. Therefore, the only capability that this architecture adds to the previously discussed architecture is that the *System Configuration* supports a confederation of tightly linked applications.

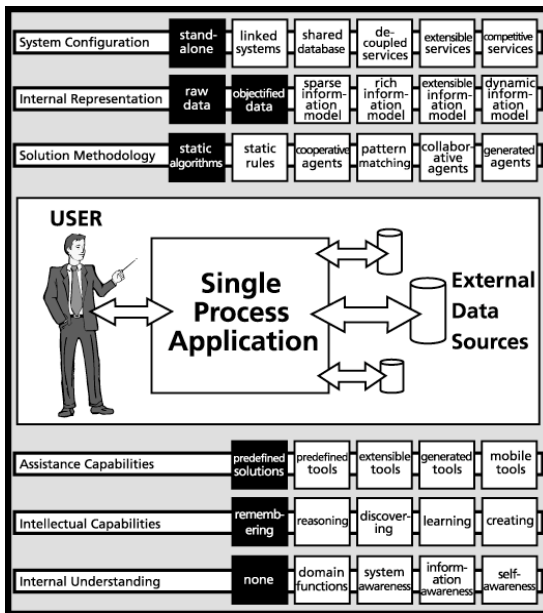


Fig.12: Single data-centric applications

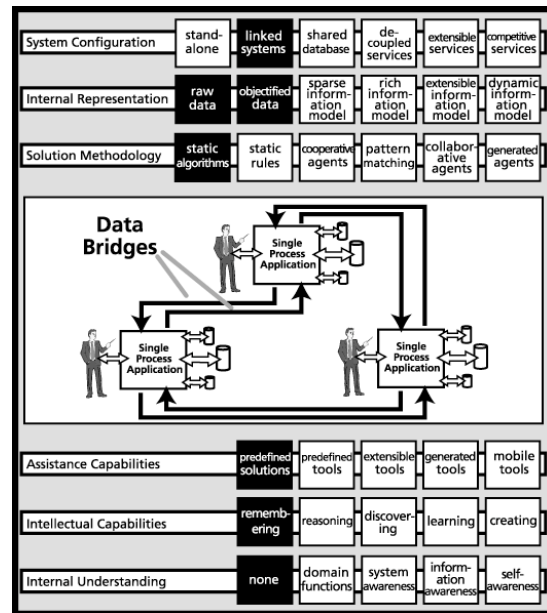


Fig.13: Confederation of linked data-centric applications

The shared database architecture (Fig.14) constitutes a major improvement over the first two system architectures by separating the data from the application and placing the former into a common repository that is external to all of the applications. The recognition that data and not the application should be the dominant component of a data-processing environment sets the stage for interoperability and intelligent software. However, it does not directly contribute any additional capabilities to the software criteria. The reason is the absence of data context, and this applies equally to the three system architectures discussed so far.

The distributed expert system architecture shown in Fig.15 on the other hand, by virtue of its internal knowledge base of rules, driven by a shared repository of facts, adds several new capabilities to the software. Each knowledge base provides relationships and therefore represents a local component of what might be characterized as a sparse



information model. This model provides adequate support for some form of automated reasoning within the typically narrow domain of each expert system. Although the expert systems (or agents) now operate as tools rather than predetermined solutions, their rules are nevertheless predefined and typically not extensible during execution.

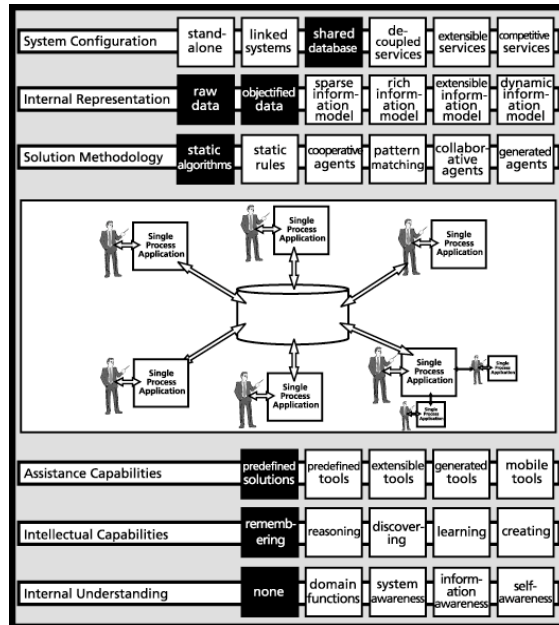


Fig.14: Shared database systems

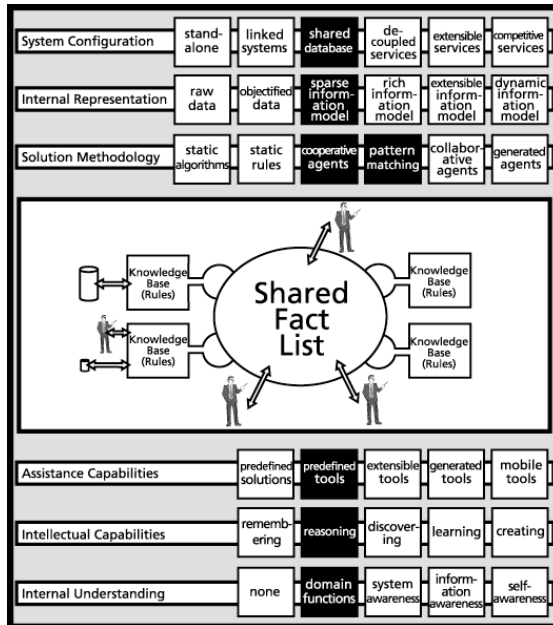


Fig.15: Distributed expert systems

For at least two reasons the concept of expert systems represents a milestone in the transition from data-processing to information-centric software. First, it showed that automated rule-based reasoning is in fact feasible and thereby allowed the field of artificial intelligence to regain some confidence after its earlier failures. Second, the largely opportunistic pattern-matching nature of an expert system laid the foundations for the notion of demon-like modules with particular data interests that could be triggered into action by data changes. Over the next decade these modules developed into *flexible* software agents that are *situated* in some environment and capable of *autonomous* actions (Wooldridge and Jennings 1995, Pohl et al. 2001 (32-33)). It was highly desirable for these agents to be capable of acting without the direct intervention of human users (or other agents), thereby providing the system with some degree of control over its own actions and internal state. The ability to achieve this level of autonomous behavior was greatly facilitated by situating the agent in a sufficiently well represented environment, which it can monitor and act upon. Triggered by its environment the agent is then able to respond to changes in the environment, exercise initiative through goal-directed reasoning capabilities, and utilize the services of other agents (including the human user) to supplement its own problem-solving capabilities in a collaborative fashion.

The desire for software agents to perform increasingly more valuable and human-like reasoning tasks focused a great deal of attention on the virtual representation of the real world environment in which the agent is situated. It became clear that the reasoning capabilities of a rule-based software agent depend largely on the richness of the virtual representation of this physical and conceptual environment. Taking advantage of the



capabilities of object-oriented languages, which allow objects to be represented as classes with attributes and relationships, a new generation of application software with internal object-based information models was born (Figs.16, 17 and 18). These are often referred to as ontology-based applications and are typically distributed in nature.

It should be noted that the term ontology is commonly used rather loosely as a synonym for object model. Strictly speaking, however, the term ontology has a much broader definition. It actually refers to the entire knowledge in a particular field. In this sense, an ontology includes both an object model and the software agents that are capable of reasoning about information within the context provided by the object model (i.e., since the agents utilize business rules, which constitute some of the knowledge within a particular domain). In this paper the common use of the term ontology as an object model (i.e., context) is implied.

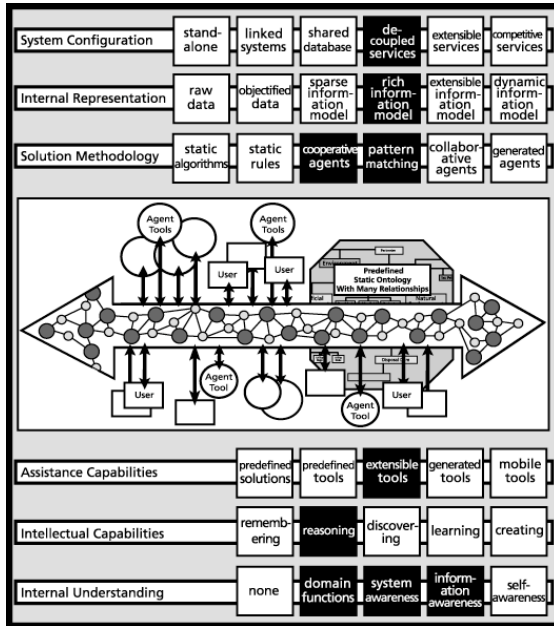


Fig.16: Information-based applications

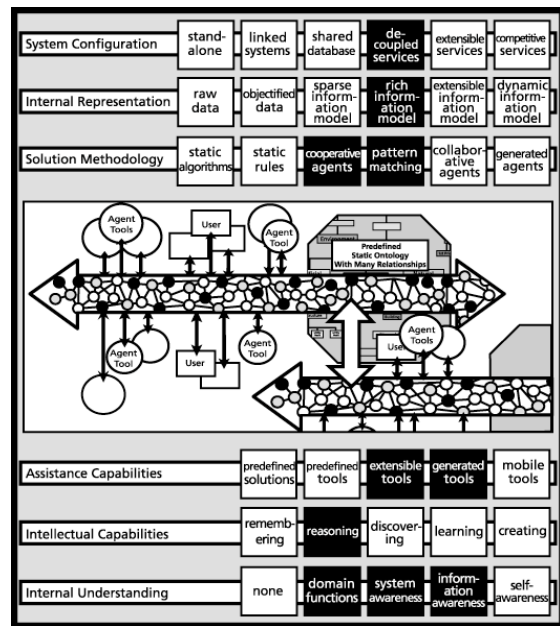


Fig.17: Information-sharing applications

The information-based architecture shown in Fig.16 typically consists of components (e.g., agents and user-interfaces) that communicate with each other through an information-serving collaboration facility. Each component includes a relevant portion of the ontology and a subscription profile of the kind of information that it is interested in receiving from this facility. Since the components have at least a limited understanding of the real world situation only the changes in the situation need to be communicated to them. While the existence of a subscription service obviates the need for computationally expensive queries in most cases, the ability to restrict the communication to changes in information also greatly reduces the amount of data that has to be exchanged. This applies equally to the information-sharing architecture and the extensible information architecture shown in Figs.17 and 18, respectively. Also, in all three of these software architectures system capabilities support (and promote) decoupled applications that interact via these services, which are accessed internally through clearly defined interfaces. Apart from simplifying the design and development of such applications, this



allows services to be seamlessly replaced as long as the replacement service adheres to the same interface definition.

The principal differences among these three architectures are related to the adaptability and accessibility of the ontology within each of the information-centric systems. First, in both the information-based (Fig.16) and the information-sharing (Fig.17) architectures the ontologies are predefined at the time the applications are compiled and cannot be changed during execution. While it is certainly possible to build into an ontology some degree of flexibility that allows for the definition of variations of existing object types during execution, the context-based definition of new objects requires the application to be recompiled. In other words, the ontology is essentially static after the application has been compiled. In the extensible information-sharing architecture shown in Fig.18, an application is able to gain and share knowledge in its interactions with other applications that have similar capabilities, or with human users. The ability of an application to extend its understanding (i.e., to increase the context within which its agents are able to reason about changes in the real world situation) is still largely a subject of research. It involves the construction of context from data with sparse relationships, which intuitively would appear to be a poor approach. However, utilizing lexical (Fellbaum 1998) and algorithmic approaches developed in the natural language research domain (Pedersen and Bruce 1998), some surprisingly promising progress has been made in this area in the commercial arena (Cass 2004).

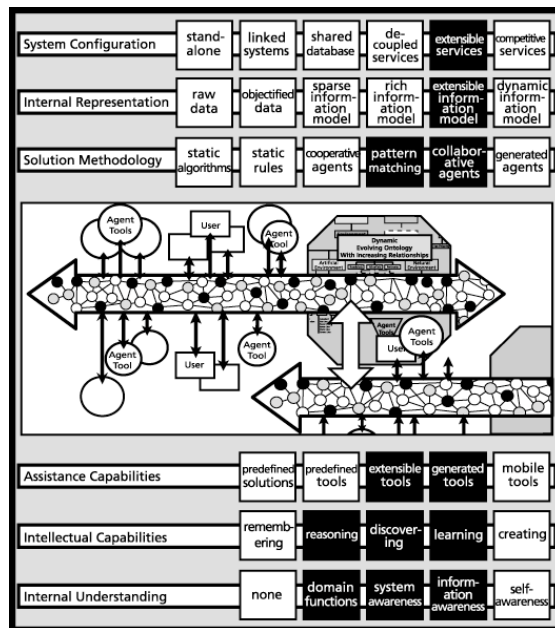


Fig.18: Extensible information-sharing applications

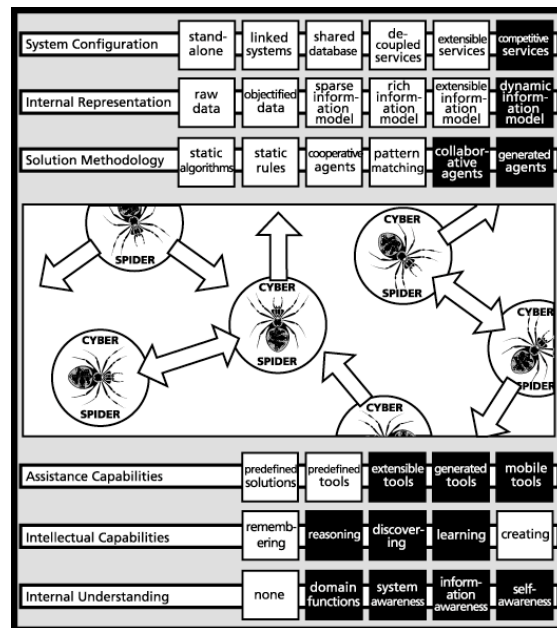


Fig.19: Semantic Web services

Second, in terms of accessibility, the subscription capabilities embedded in the components of an information-based system can be equally applied across multiple systems by having the information-serving collaboration facility of one system subscribe to the information-serving collaboration facility of another system. This is potentially a



very powerful approach that allows information-centric systems to scale as clusters of networks within a networked environment.

The software architectures described so far (i.e., Figs.12 to 18) progressively evolved from stand-alone systems that encapsulate their own data, to systems that are able to share data based on predefined formats for data representation, to systems that incorporate rich but static information models and are able to support automated reasoning capabilities, to systems that are able to extend their internal information models in collaboration with similar ontology-based external systems. Within this evolutionary path the transition from data-based to information-based internal representation schemas is the enabling step that has endowed software with increasingly intelligent capabilities. However, the fundamental mechanism for achieving these capabilities is the ability to automatically reason about changes in the current state of the situation described by the information model. Once expert systems (Fig.15) had demonstrated that reasoning capabilities could be provided by conditional rules (i.e., a knowledge base of productions) and triggered by changes in a simple fact-list, it became clear that much could be gained by expanding the representational capabilities of the fact-list and incorporating in it many of the relationships that were formerly encoded in the rules of the knowledge base. This contributed to the formal separation within an application of the representation (i.e., object model or ontology) and the logic that is applied to this representation by agents. While initially most of the complexity of these ontology-based applications continued to reside in the agents, the availability of more powerful modeling concepts and tools is gradually allowing more and more of the complexity to be moved from the agents into the ontology. This suggests a trend that appears to mirror the earlier separation of an application from the data it is designed to manipulate (Fig.14), namely the separation of the information representation from the applications that incorporate reasoning capabilities. The combination of this trend with an information-centric Internet-like environment will cast applications into the role of capability-based services.

This is the emerging concept portrayed by the semantic Web services architecture shown in Fig.19. However, before describing this software architecture it is necessary to briefly discuss the architecture and capabilities of the existing data-centric Web services. They typically comprise a Web-Server that utilizes the Hyper-Text Transfer Protocol (HTTP) for communication, the Universal Description Discovery and Integration (UDDI) protocol as part of the standard definition of Web services registries, and a Registry that already contains an entry for the accessing application as well as any number of other Web services. UDDI is an international standard that defines a set of methods for accessing a Registry that provides certain information to an accessing application. For perhaps historical reasons UDDI is structured to provide information about organizations, such as: who (about the particular organization); what (what services are available); and, where (where are these services available).

The Simple Object Access Protocol (SOAP) defines a protocol for the direct exchange of data objects between software systems in a networked environment. It provides a means of representing objects at execution time, regardless of the underlying computer language. SOAP defines methods for representing the attributes and associations of an object in the Extensible Markup Language (XML). It is actually a meta-protocol based on



XML that can be used to define new protocols within a clearly defined, but flexible framework.

Web-Services are designed to be accessed by software. In the currently prevalent data-centric software environment they are generally clients to the middleware of data sources. The middleware collects the required data and sends them back to the Web service, which reformats the data using the SOAP protocol and passes them onto the requester. Depending on its original specifications, the requesting application will have the data downloaded on disk or receive them directly on-line. If the Web service is a data-centric application then a data-to-data translation must be performed in much the same way as is necessary when passing data between two data-centric applications.

Returning to the software architecture shown in Fig.19, the emphasis is on the word *semantic*. In this architecture the semantics are embedded in an ontology, which provides the necessary context for automated reasoning. A semantic Web service, therefore, is an ontology-based application (may be mobile) with certain capabilities. Given a particular intent it seeks the services that it determines to be necessary for satisfying this intent. Having found one or more such Web services it self-configures itself with these discovered services into a temporary system. Depending on needs and circumstances this transitory system may reconfigure itself by discarding existing members when their capabilities are no longer needed, adding new members when other requirements arise, or dissolving itself altogether once it determines that its intent has been adequately executed.

To meet these capability objectives a semantic Web service reaches the highest-level criteria in all but one of the six software characterization categories shown in Fig.11 and 13. First, it operates in a competitive environment where it can select a service from several offering candidates, and presumably negotiate the terms of acceptance. Second, it incorporates a rich and extensible information model that will change dynamically as the semantic Web service discovers, collaborates with, and shares ontology fragments with its transitory partners. This provides the ability to create and maintain a desirable degree of common understanding within the self-configured system. Third, by virtue of this common understanding the agents of each member of the system are able to collaborate beyond the boundaries of the particular semantic Web service that they are housed in. Furthermore, any new agents that may be generated in response to a recently emerged need will likewise be able to collaborate globally within the system.

Forth, the agents, which constitute the primary assistance capabilities of the system, become highly adaptable tools. They are extensible, they may be generated dynamically during execution to satisfy emerging new needs, and they can be implemented to operate in a mobile mode. Fifth, the collective intellectual capabilities of the system include the ability to discover capabilities that may be made available by external services and the ability to increase its understanding of context by extending the ontologies of one or more of its members through their interaction and the addition of new members to the system. It can be argued that this dynamic acquisition of new knowledge is a form of learning, however, it does not necessarily imply an ability to create new knowledge. Whether or not the semantic Web architecture will be able to create new knowledge is very much a matter of conjecture at this time.



Finally, in the *Internal Understanding* category the semantic Web architecture is rated to have the potential for reaching the highest criterion, 'self-awareness'. As further explanation it should be noted that this characterization category has been based entirely on the representational capabilities of ontologies, since the author is not aware of any alternative method for creating internal understanding in software. Ontologies are capable of not only representing physical objects such as buildings, conveyances (e.g., cars, boats, aircraft), supplies, weapons, and organizations, but also conceptual objects such as the notions of mobility, threat, privacy, security, consumability, and so on. This has been the predominant focus of ontologies to date. However, in addition, ontologies are able to represent the behavioral characteristics and relationships of the components of the software system itself. This is the domain of autonomic computing discussed previously, whereby a system is charged with continuously monitoring its own performance, exposure to intrusion, vulnerability to failure or degradation, and implementing remedies spontaneously as needs arise.

A third and much higher level of representation is the ability of a system to express to another system its nature, interests and capabilities. What is implied here is not simply an indication that this is a software system written in the Java computer language, supporting the following interface protocols, and listing explicitly defined capabilities. This kind of explicit introduction is similar to the directed search capabilities that are offered by the query facilities of any database management system available today. To fully support the requirements of 'discovery' the system should be able to communicate its nature, interests and capabilities in a conceptual manner. The analogy in the database domain is a conceptual search capability, where the target of the search is only vaguely defined as being something like something else and is expected to extend beyond the boundaries of any particular database or database management system (Pohl et al. 1999, 69-74). The ability to represent this kind of 'self-awareness' in an ontology appears to be well beyond current knowledge modeling capabilities.

### **The Semantic Web Initiative**

It is unlikely that anyone predicted in the early 1970s when the Internet first appeared on the foundations of the ARPANET project funded by the U.S. Department of Defense Advanced Research Projects Agency (DARPA) that some 30 years later in 2003 the Internet would be used on a regular basis by more than 600 million people and serve as the preferred medium for close to (US)\$4 trillion in business transactions. However, although the Internet provides almost instant global connectivity and potential access to an enormous volume of information, all of that information is stored in a low-level form as data. As a result, even the most powerful search engines can do little more than pattern-match on keywords as they attempt to retrieve user requested information. The product of such data searches is typically hundreds of information source references that may or may not be useful to the human user. The latter may then have to spend hours reviewing each source to determine whether it is relevant to the purpose of the search. This was not the intention of the creators of the World Wide Web (Berners-Lee and Fischetti 1999).

There is a valid concern that the more successful the Internet becomes in providing global connectivity to millions of users, with a corresponding exponential growth in the



availability of information, the less useful it will become as a source of information. Succinctly stated the evolution of the Internet, like software systems in general, has been driven by the ability of computers to rapidly manipulate vast amounts of data without any understanding of the meaning of the data being processed. The vision of the Semantic Web is intended to overcome this serious deficiency by making the information on the World Wide Web understandable by computer software. Signs of this vision have become evident with the increasing interest in adding semantics to data.

The historical development of data manipulation and storage techniques first showed a preoccupation with efficiency, leading to the deletion of context in favor of the arrangement of data into neatly packaged records. This appeared to be a perfectly logical approach in line with the notion that the application, and not the data, is the enabler of the desired functionality. Accordingly, the data requirements were encapsulated in the application, and even when programming languages began to acquire object-oriented facilities the more prominent role assigned to data was largely hidden from the users deep inside the application.

All of this seemed to work quite well until the need for interoperability and the attendant requirement for the exchange of data among applications surfaced. Two problems were quickly recognized. First, since each application controlled its own data schema the linking of multiple applications required application-to-application data mappings that led to hardwired systems. It soon became apparent that while it was possible to maintain the vertical flow of data within each of these stovepipe systems, it was inordinately difficult to exchange data horizontally between stovepipes. The second problem centered on this need for horizontal interoperability: How to exchange data between two stovepipe systems so that the receiving application will be able to process the imported data in a useful manner? There appeared to be two possible approaches for addressing this problem. To explicitly predefine the data exchange format and content, or to add meaning-identifiers to the data. The first approach, while providing a modest level of interoperability in the short term, exacerbated the problem in the long term. The hardwired data bridges were difficult and costly to maintain, provided little (if any) flexibility, and constituted multiple system failure points. The second approach led to the definition of standard data exchange protocols that conveyed to the receiving application at least some indication of the meaning of an imported data package. Of these protocols the Extensible Markup Language (XML) is rapidly gaining widespread acceptance. XML provides a degree of syntactic interoperability through nested data record delimiters (i.e., Unicode characters), data meaning-identifiers (i.e., tags), and links to other resources (i.e., Uniform Resource Identifiers).

Does a protocol like XML convey sufficient meaning to support horizontal interoperability? The answer is, no. The XML elements that are added to a data exchange package to convey meaning are of value only if the receiving application understands the name of each element. For example, the tag name “address” is only useful to the receiving application if it interprets that name to have the same meaning as the meaning assumed by the sending application (i.e., “address” could mean street address, e-mail address, object reference ID, etc.). However, XML does provide a syntactic foundation layer on which other layers such as the Resource Description Framework (RDF) can be



built. The combination of these layers will serve as the enabling structure of what is referred to as the Semantic Web.

The vision of the Semantic Web is an information-centric environment in which autonomous software services with the ability to interpret data imported from other services are able to combine their abilities to accomplish some useful intent. This intent may range from simply finding a particular item of information to the more sophisticated tasks of discovering patterns of data changes, identifying and utilizing previously unknown resources, and providing intelligent decision-assistance in complex and time-critical problem situations. An example of such an environment is the TEGRID proof-of-concept system that was first demonstrated by the Collaborative Agent Design Research Center (CADRC) during an Office of Naval Research Workshop in Washington in September 2002 (Gollery and Pohl 2002). A brief summary of this demonstration is provided in the following section.

### TEGRID: An Experimental Web Services System

The principal components of the TEGRID demonstration are ontology-based Web services that are capable of seeking and discovering existing Web services, extending their own information models through the information model of any discovered Web service, and automatically reasoning about the state of their internal information models. As shown in Fig.20, these components (referred to as Cyber-Spiders in TEGRID) consist of three principal components: a Web server; a semantic Web service; and, an information-centric application.

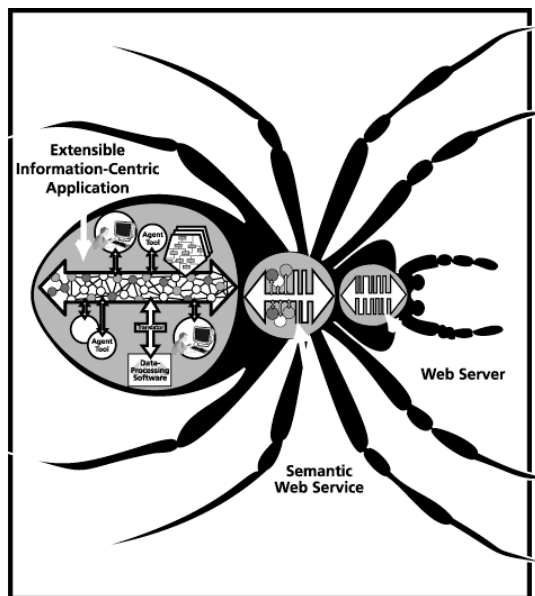


Fig.20: Anatomy of a Cyber-Spider

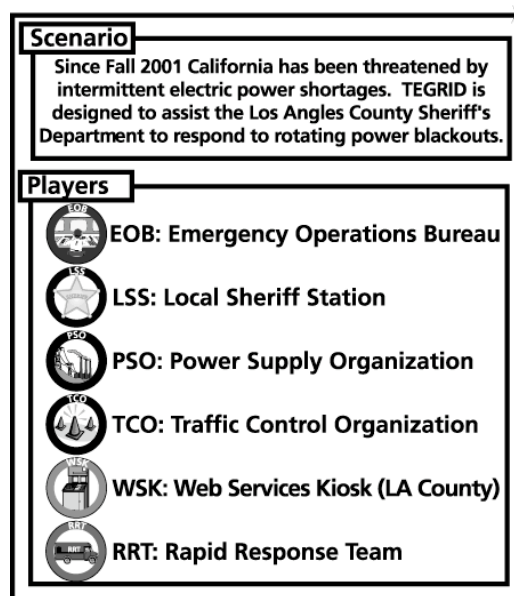


Fig.21: Cast of TEGRID players

The Web server, utilizing the standard Hypertext Transfer Protocol (HTTP), serves as the gateway through which the Cyber-Spider gains access to other existing Web services. Existing Web servers primarily provide access to Hypertext Markup Language (HTML) data sources and perform only simple operations that enable access to externally



programmed functionality. However, these simple operations currently form the building blocks of the World Wide Web.

The second component of a Cyber-Spider is a semantic Web service (i.e., a Web service with an internal information model). A Web service is accessed through a Web server utilizing standard protocols (e.g., UDDI, SOAP, WSDL, SML) and is capable of providing programmed functionality. However, clients to a standard Web service are usually restricted to those services that implement specific predefined interfaces. The implementation of Web services in the Internet environment allows organizations to provide access to applications that accept and return complex objects. Web service standards also include a limited form of registration and discovery, which provide the ability to ‘advertise’ a set of services in such a way that prospective client programs can find services that meet their needs. The addition of an internal information model in a semantic Web service allows the storage of semantic level descriptions (i.e., information) and the performance of limited operations on these semantic descriptions. In other words, the semantic Web server component of a Cyber-Spider is capable of reasoning.

The third component of a Cyber-Spider is one or more information-centric applications. These applications are designed to take advantage of the resources provided by a number of semantic Web services, enabling them to reason about the usefulness of each service as a core capability within a more sophisticated set of discovery strategies. Moreover, the application component is able to construct relationships among the information models of different services, with the ability to integrate services without requiring agreement on a common information model.

With these three components Cyber-Spiders are at least minimally equipped to operate in an Internet environment as autonomous software entities, capable of: discovering needed services; accepting services from external offerers; providing services to external requesters; gaining context through an internal information model; automatically reasoning about available information; extending their information model during execution; extending their service capabilities during execution; and, learning from their collaborations.

### ***The Cast of Players***

Based on the scenario described in Fig.21, the TEGRID cast of players includes six semantic Web services: the Emergency Operations Bureau (EOB) of the Los Angeles Sheriff’s Department; several Local Sheriff Stations (LSS); a Power Supply Organization (PSO); a Traffic Control Organization (TCO); several Rapid Response Teams (RRT); and, a Los Angeles County Web Services Kiosk (WSK).

Fundamental to each player are three notions. First, each player operates as an *autonomous* entity within an environment of other players. Most, but not all of the other players are also autonomous. This requires the autonomous players to be able to discover the capabilities of other players. Second, each autonomous player has a sense of *intent* to accomplish one or more objectives. Such objectives may range from the desire to achieve a goal (e.g., maintain situation awareness, coordinate the response to a time-critical situation, or undertake a predetermined course of action following the occurrence of a particular event) to the willingness to provide one or more services to other players. Third, each player (whether autonomous or not) is willing to at least *cooperate* with the



other players. In some cases the level of cooperation will extend to a collaborative partnership in which the partnering players contribute to the accomplishment of a common objective. In other cases the cooperation may be limited to one player providing a service to another player, without any understanding or interest in the reason for the service request.

To operate successfully in such an autonomous Internet-based environment a Cyber-Spider player should be endowed with the following capabilities:

1. Subscribe to information from external sources (e.g., alerts, ontology extensions).
2. Accept subscriptions from external clients.
3. Dynamically change its subscription profile.
4. Extend its internal information representation.
5. Extend its own service capabilities.
6. Generate new agents for its own use.
7. Describe its own service capabilities to external clients.
8. Seek, evaluate and utilize services offered by external clients.
9. Provide services to external clients.
10. Describe its own (intent) nature to external clients.

The Cyber-Spiders in TEGRID are capable of demonstrating eight of these ten desirable capabilities. The ability of a Cyber-Spider to dynamically change its subscription profile, while technically a fairly simple matter, was not implemented because it is not used in the demonstration scenario. The ability of a Cyber-Spider to describe its own nature to external clients, on the other hand, is technically a much more difficult proposition. It will require a Cyber-Spider to have an understanding of its personality as a collective product of its internal information model and the relationship of that model with the external world. At best this must be considered a challenging research area that is beyond the current capabilities of information-centric software systems.

### ***The Capabilities***

The objective of the TEGRID scenario is to demonstrate the discovery, extensibility, collaboration, automatic reasoning, and tool creation capabilities of a distributed, just-in-time, self-configuring, collaborative multi-agent system in which a number of loosely coupled semantic Web Services associate opportunistically and cooperatively to collectively provide decision assistance in a crisis management situation. Specifically, these capabilities are defined as follows:

***Discovery:*** Ability of an executing software entity to orient itself in a virtual cyberspace environment and discover other software services.

***Extensibility:*** Ability of an executing software entity to extend its information model by gaining access to portions of the information model of another executing software entity.

***Collaboration:*** Ability of several semantic Web Services to collaboratively assist each other and human users during time critical decision-making processes.



**Reasoning:** Ability of a software agent to automatically reason about events in near real-time under time critical conditions.

**Tool Creation:** Ability of a semantic Web Service to create an agent to perform specific situation monitoring and reporting functions.

The reasoning capabilities available in TEGRID are performed by software agents that are components of the players (i.e., the Cyber-Spiders). In other words, agents are predefined clients within player systems and perform internal functions that are necessary for the particular player to deliver its services and/or accomplish its intent. The following agents (i.e., collaborative tools) are available in the current TEGRID implementation:

**Risk Agent:** Assists the Emergency Operations Bureau to identify high-risk entities in the jurisdictional region of an activated Local Sheriff Station.

**Deployment Agent:** Assists the Emergency Operations Bureau to determine whether Rapid Response Team support is required for a particular activated Local Sheriff Station.

**Power Level Agent:** Assists the Power Supply Organization to determine if the electric power demand has exceeded supply.

**Situation Agent:** Assists the Emergency Operations Bureau to prepare and update its Status Report.

**Station Monitor Agent:** Assists the Emergency Operations Bureau to identify all Local Sheriff Stations that will experience power blackouts during the current and next blackout cycle.

**Status Agent:** Assists a Local Sheriff Station to prepare and update its Situation Status Report.

**Local Station Agent:** Assists a Local Sheriff Station to determine whether sufficient local resources are available to deal with current conditions.

**Scheduling Agent:** Assists the Emergency Operations Bureau to assign Rapid Response Teams and equipment to situations requiring their involvement.

**Incident Agent:** Assists the Emergency Operations Bureau to monitor the response to a particular situation supported by one or more of its Rapid Response Teams.

**Routing Agent:** Assists the Traffic Control Center to determine alternative routes to a particular situation location.

### ***Demonstration Summary***

Since the complete TEGRID demonstration scenario has been described elsewhere (Gollery and Pohl 2002) it will suffice here to summarize some typical events and automated reactions.

**Orientation:** The players orient themselves by accessing one or more directories of available services and registering an information subscription profile with those services that they believe to be related to their intent (Fig.22).



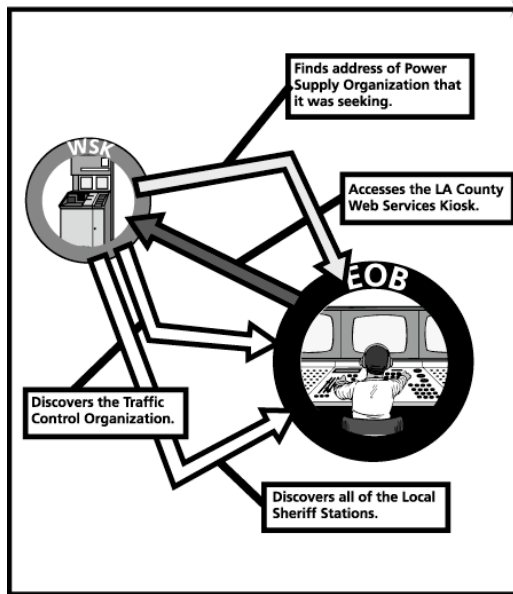


Fig.22: Orientation and discovery

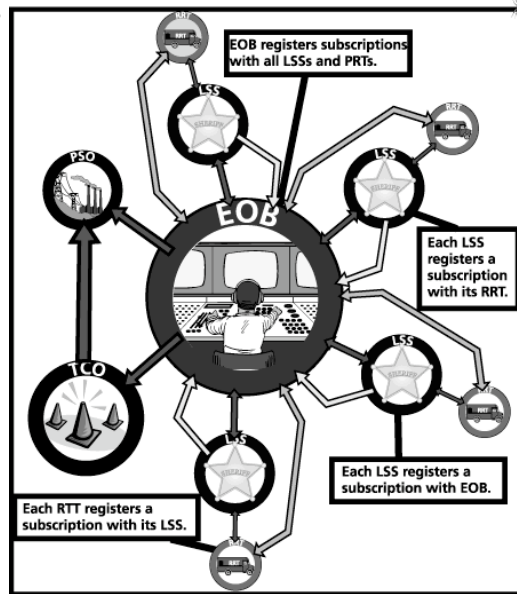


Fig.23: Information subscription

**Subscription:** The players access the services that they require to achieve their intent, register appropriate subscription profiles, and query for information that they believe to have a need for (Fig.23). For example, the Emergency Operations Bureau registers a subscription profile with each Local Sheriff Station, which includes all current police unit locations, mission completion events, new mission events, and any information changes relating to the availability of its Rapid Response Teams. Then queries each Local Sheriff Station for all information relating to its Rapid Response Teams and extends its information model. Finally, registers subscription profiles with each Rapid Response Team, the Power Supply Organization, and the Traffic Control Organization.

**Collaboration:** The Power Supply Organization first alerts its subscribers that a rolling power blackout condition is imminent (i.e., will commence per predefined schedule within 15 minutes) and subsequently alerts its subscribers that the rolling power blackout has commenced. The Emergency Operations Bureau (EOB) utilizes its Situation Agent to prepare the first version of the 'EOB Situation Status Report'. Then alerts all Local Sheriff Stations, in whose jurisdictions the next scheduled set of blackouts will occur, to prepare for potential deployment. And, finally, warns the Rapid Response Teams assigned to assist the Local Sheriff Stations in whose jurisdictions the next set of blackouts are scheduled to occur, to prepare for potential deployment. Consequently, all activated Local Sheriff Stations utilize their Status Agents to prepare the first version of their 'Situation Status Reports', the Local Sheriff Stations in whose jurisdiction the next set of blackouts is scheduled to occur, prepare for deployment.

### **Demonstration Results**

The objectives of the TEGRID project were three-fold. First, to explore the primary capabilities that would be required of semantic Web services operating as largely



autonomous decision-support components in a self-configuring, just-in-time, intelligent decision-assistance toolkit of collaborating software agents. Second, to determine if the currently available information-centric software technology could support at least basic (i.e., meaningful and useful) implementations of these required capabilities. And, third, to build a working experimental system that could serve as a test-bed for longer term research studies focused on the behavioral characteristics of self-configuring intelligent systems in general, and the ability of such systems to deal with specific kinds of dynamic and complex problem situations.

The demonstration showed that, today at a base level of functionality and in the near future at a much more sophisticated level, a Semantic Web environment will be able to support semantic Web services with the ability to: discover desired existing external services; accept and utilize services from external offerers; provide services to external requesters; gain understanding through the context provided by an internal information model; automatically reason about available information within the context of the internal information model; extend the internal information model during execution; spontaneously generate new agents during execution as the need for new capabilities arises; and, learn from the collaborations that occur within the cyberspace environment.

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## Posturing to Exploit the Power of Emerging Technology

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When I first received the invitation to present at this Office of Naval Research (ONR) conference it occurred to me that I should address the question of how best we in the Department of Defense (DoD) should posture ourselves to accept the rapidly emerging technology, particularly the information technology (IT)? What can we do? Are we ready to accept this technology?

First, I would like to take about 10 to 15 minutes to set the stage for where DoD is right now, at least where the Marine Corps is right now, and what I have been preaching as I have been going out and talking with groups, and what I have written for publication. This will give you a sense of where the push is in DoD. Then we will take a look at the impediments to our accepting the technology, the precise response or what we have to do to change, and then I will wrap it up with a vision. I love the opportunity to toss this vision out and let you all have it to chew on.

As we look across the Department for solutions to problems that are revealed by our ever increasing appetite for more and more information, we are confounded by the speed at which information comes to us. It is very dynamic information, it is continuously changing and coming at us very quickly. We don't yet have the systems to coalesce that information and display it to us. Therefore, we end up with a biowave of information in a very dynamic environment. That spells disaster all by itself. What we need is some assistance in processing all that data into actionable information, or better still, into *actioned* information. Too often we become mesmerized by the fancy point and click GUIs that are put on our old systems, and we don't really notice that we are actually doing more work than we did before. We are just doing the work on a pretty face. That is sort of akin to having difficulty managing your schedules and getting the latest and greatest leather-bound organizer with a nice golden pen. It is not going to make the schedule any better. Instead, I am just going to spend more time working on my schedule. What we really need from industry is a solution that will help to relieve us from some of the mundane tasks and present the information to us. Perhaps, even make some intelligent recommendations or, better still, take some action. Most importantly such capabilities should take complex situations that are very dynamic and come back with either *actioned* or actionable information.

For example, consider the virtues of advanced or intelligent computer-aided design (CAD) software that is used in manufacturing. You know, the kind of software that is capable of selecting the appropriate material, sizing components, automatically calculating the correct angles, checking code compliance, estimating costs, and taking into account all of those variables that change every time you go from aluminum to steel or some other kind of alloy. Those decisions can all be made the moment the stylus touches the screen. It is an incredible process. I have a son who is an engineer at Ford Motor Company. I have been to his office and watched him and his colleagues as they use the system. It is an incredible capability, which provides access to information that has been enhanced by a computer-based reasoning tool. It is not Hal



9000, the errant artificial intelligence from *A Space Odyssey*. A human engineer is still doing the design work, but the engineer has been enabled by access to information that has already considered many of the variables that impact the final design solution.

If our manufacturing industry did not have this capability, it would probably go out of business. Right now, at least the high end of ship building and manufacturing would be noncompetitive, without it. So, industry is putting a lot of effort into that area. We are not, and the question is why is DoD not putting the same level of effort into that area? In respect to automation solutions, we in DoD seem to be content with just speeding up the existing process, going a little faster, or seeing a prettier picture. In our more creative moments we may become involved in designing some algorithms to determine if we are staying within some boundaries or if we are doing things fairly efficiently, but rarely do we ever ask the computer software to really dig in and automatically reason about a problem. Quite frankly I could probably count all those kind of capabilities on one hand.

Now we are going get to what I believe you are really interested in. Are we afraid of Hal? Is that the problem? Or, is it just that this black box voodoo escapes our confidence? Is it that we cannot believe that this machine can actually reason and give us some valuable opinions or recommendations, or maybe even solutions? We certainly do not appear to understand the potential of the computer to function intelligently. There are too many of us that simply refuse to accept the idea that this plastic box sitting beside our desk can function intelligently. It is really important that we think about that for just a second. We are going to come back to this question later when I suggest how we have to posture ourselves to better receive this emerging technology. We, in DoD, really need to understand this technology that you (i.e., industry) have and that you are working on and that you are developing. I need to look at every single automation requirement that comes through my office from two perspectives: (1) from the vantage point of the Marine Corps Combat Development Command; and, (2) as a Marine Corps representative on the Joint Capabilities Board in the JROC system. Every single system that comes through should be bounced against the question: Does this system just speed up the process and make it a little easier, or does it go the full measure and rise to the level of intellect and our ability to reason? If it does not then we ought to ask ourselves why we have accepted dumb technology, and look for better technology. It has to be that forceful. Right now we don't have a forcing function to make it happen. Yet I am suggesting that if that question were to be asked in the requirements process, then that could be the forcing function.

For those who are afraid of the new technology, I would suggest that the aerospace industry is well into it. Every time you fly in an airplane you are relying on this kind of technology. These airplanes fly in a super-dynamic environment, with constantly changing weather conditions, threat conditions, traffic, and many other factors. Yet, those companies manage those airplanes to the dollar (probably to the penny) in terms of performance. They know exactly when to speed up, slow down, to change altitude, to take advantage of different weather, and so on. The guys up in front, the pilots, are really in my opinion information management experts. They are receiving lots of information. Some of the information is automatically translated into actions, without the knowledge of the pilot. Sometimes he is given a follow-up message that says "I just did something". Particularly in our new airplanes, without the computer taking immediate actions the airplane would cease to fly; - that is *actioned* information. Hal is in that airplane that you are



flying in. So, for those who may be afraid of artificial intelligence and these reasoning capabilities, there are airplanes out there that you are flying in that depend on these capabilities.

Why can't we take that same technology and build it into our deployment systems or tactical operations systems or budget development systems? Why can't these systems have an ontological brain; - a logic that includes characteristics and interrelationships? The answer is that we can have the technology, it's do-able. If we had a machine that could help with some of the reasoning tasks, particularly in a very dynamic environment, then that could be very important. Let's take that really mundane budgeting task. This is usually a late Friday afternoon kind of drill that comes as a "what if" request. "What if we gave you an extra two million dollars, where would you put it to get the most impact? Have that response to me by Monday morning." We can handle those drills and we do it on the backs of hardworking people with stubby pencils. What if we had a machine that could do this in a very dynamic environment, and come back to us with an answer "... yes, that looks good but what about these third order effects down here?" A machine that could perform this task so quickly that it could be measured in seconds, and not hours or days. A machine that can look at capability sets in relationship to each other and the problem as a whole; - not a piece of equipment but the capability that it represents.

It is an intriguing thought to have a system that is capable of categorizing actions. Some of these actions would be acted upon without our explicit knowledge. We could call this *actioned* information. The system would also do other things such as letting me set a threshold so I could say "... based on dollars or distance or time or risk or whatever the threshold measurement is such and such". I could set the threshold where I am comfortable and the machine would automatically *action* on information below that threshold. There would be many other options that would be continuously available, displayed like in the cockpit of an airplane in a manner that would be sensory and friendly; - that I could absorb quickly and easily in a combat operations center.

Well that is an interesting thought. If only I could have a system that can do that for me. Now my mind begins to race: Where can I employ that kind of system? Can I put it in a tactical Command and Control Center? The problem is, if we now leave this thought just kind of loitering around here in our cranial air space and call it an intriguing thought, then we find ourselves right back to where we started. We are sub-optimized within our own GUI-enhanced tailored systems. It can't remain just an interesting thought. We have to do something with this. Personally, I don't think we have even scratched the surface of the potential capabilities of these intelligently operating computers. I don't think we have really scratched the surface of what we could do with these machines. In practical terms, our fear of Hal or the black box voodoo is holding us hostage to a high speed old plane kind of mentality. We just think that the more data we receive, the more we pile in, the more we stack up and put on spreadsheets, the better a job we will do. Perhaps we can organize it a little better and put a better face on it, and that will do a better job. It has been argued that during World War II General Patton dealt with about 300 bits of information that came to him each day. This is the information over which he had some influence and on the basis of which he could take some actions. If you really think about it, Generals in the field will be fully engaged 18 to 20 hours per day. In those 18 to 20 hours, Patton is going to take 300 pieces of information that he is going to do something with. Let's do the mathematics, he's busy, and by all accounts General Patton was a very capable general officer. Now let's consider the same level



of command in Operation Iraqi Freedom (OIF) with having to deal with about 600,000 bits of the same kind of information. Now it doesn't matter what the actual numbers are, we all know that we have a lot more information available today than we had back then when it was a matter of just how fast the runner could get back there with his canvas bag and open it up and give him the information. General Conway during OIF was just deluged with information, and his staff was just buried in information.

What bothers me most about this is that it is good that the information is coming in. Everybody did a wonderful job in gathering that information and sending it to us. However, I don't think that General Conway can process much more information than General Patton did, - maybe 300 pieces a day and that leaves all the rest without action. The question that comes into my business mind is: What's the opportunity cost? What did I lose because I didn't take advantage of all of that information? Now maybe some of you might look at it and say I would do nothing. There is no action that I can take that would change anything. However, I would suggest that if you could take all of those little bits of information and put them together and make only a 5% improvement on the battlefield, in terms of ammunition or fuel consumption or distance traveled or if it saved the life of one Marine, then it is worthwhile. How can we let that information go by without action, if it could save the life of one Marine, - it would be unconscionable.

Our current inclination is to focus on prioritizing all of that information. We triage it when it comes in to the combat operations center and we act first on what we think is most important, and we work until time expires or we expire. The truth is that we are never sure that we are getting the most important information. It is mostly a matter of 'first in first out'. This technique may be valid if you are in a gator infested swamp and you are just trying to stay alive for a few minutes. It would have to be acceptable if that is the only tool you have, however, I would like to suggest that we have some other tools that we should take advantage of. We live in a time where information is exponentially more available than it was in years past. Also, we have problems that require more precision solution than ever before. Just for a moment let's talk about precision and what the expectation are for weapons. Today, we don't tolerate a weapon being a minute too early or a minute too late. The delivery must be precisely on time, and that is precisely when somebody is transmitting on a radio or precisely when a group begins a meeting. We want precision to the minute, or even to the second, so that we can measure opportunity costs. If you could look at all those decisions every day that we didn't make, if you could sort through that data, then I bet you could quantify the opportunity costs of not looking at that data. With that in mind, we really need to avail ourselves of the benefits of computer software with intelligent reasoning capabilities.

So the question is, how do we get there? I believe that there are already some intelligent systems available and others are on the threshold of implementation. The problem is that we have to overcome the inertia of some old think bureaucracy that is out there alive and well. This is a tough opponent to have to fight every single day. However, the future is wide open with opportunities and our minds must be equally open if we are going to grasp the very crisp edge of the possible. This is essential as we in the Marine Corps approach the complexities of concepts such as sea-basing, where schemes of maneuver with an increased number of variables need to be executed precisely in very time constrained environments with fewer and fewer resources. All of this is becoming increasingly difficult and we need help with this increasing complexity.



My intent in advocating these new capabilities in DoD and, in particular in the Marine Corps, is to challenge the old ways with a generation of adaptive decision support tools. We have a true transformation technology on our doorstep. It is here now and we have to decide what we are going to do with it. Are we going to kick it into the curb or welcome it in? We have to have the courage to make the decision now. I know that there are some of us who are process-oriented. I fully understand that just introducing a technology is not enough. We also have to review all of the processes. If you are willing to accept the fact that this technology is out there and you want to be able to use it, then you are going to have to take a look at your existing processes. You have to ask yourself, do I have to re-examine them and perhaps change the way I am doing things. It is not enough to simply make everything go faster. Let's go the full measure and also review the processes as we apply the technology.

Perhaps the greatest challenge that we face today is, tomorrow. We are simply not postured to face tomorrow today. We tend to put off dealing with tomorrow until tomorrow. I see our difficulty with posturing as being related to two aspects of our organizations, their cultural state and their willingness to commit resources. Let's talk first about the cultural state. Jim Collins writes in his fabulous book *Good to Great* "... good to great companies think differently about the role of technology." They never use technology as a primary means of igniting transformation, yet paradoxically they are the pioneers in the application of carefully selected technologies. We seem to find it difficult to embrace technology. We, that is DoD and in particular the Marines, are generalists. The volume of available technologies is overwhelming to us. We go to a trade shows and we are absolutely intimidated. We usually wait for somebody to take the technology and put it into a product and then knock on the door and sell us the product. Unfortunately, that does not take the most advantage of the technology, because the product may not cover the entire range of our requirements.

Now let's look at the issue of organizational commitment. The nasty truth about commitment in this town is that an organization's strategy is not that glossy book laying on the coffee table or the framed poster in the main lobby. An organization's true strategy is what comes out of the mill known as 'resourcing'. That is what we pay for. It is not the rhetoric that proceeds it, although there is a lot of that. There is a lot of talk about what we want to do, what we can do, what we should do, and what the vision is. However, the true strategy is dictated by what we put money against, which says what we are going to do. So we can disregard all of the dust and debris that comes out of the budget building process, the speeches and all the posturing, and look at the POM instead. That is where your organization is, that is its strategy, and that is what we have to influence. We have to get in on the front end, because if we don't put into the POM a real assessment of tomorrow, then tomorrow is going to get here before we are adequately prepared. This is a matter of technology starvation, because if we get to tomorrow and there's no technology or only old technology, then we are simply exacerbating the same problem that we have now.

I see those two impediments to accepting emerging technology. The question then becomes: What can we do about it? A few minutes ago I talked about the cultural state of an organization, and that is really an institutional climate for change. I am going to make an assumption and it is a really big assumption, that the climate is favorable and accepting of change. I can pretty well



envision what I want in terms of a final capability and I can also begin to see what I have to do in terms of requirements. The problem is that what I am envisioning is in the framework of today. I don't know what all of you are doing. I don't know enough about the technology that is out there that could help me fill those requirements of tomorrow. In the absence of that knowledge, I just grind along designing requirements based on what I know to exist right now. The best I will get is when I throw these requirements over the fence to the buyers in the acquisition world and they go out and find some new technology. However, frankly what they will most likely find is technology that was introduced several years ago and is still being amortized off some company's books.

So what I am asking you for is concurrent input. Now there are probably some lawyers and contractors who are starting to squirm and wiggle around, but let them squirm and wiggle around, we'll figure them out later. What I need is to know from you as we prepare the requirements is: What technology is under development? How will I be able to use it? How can I leverage it? Without this information I am going to shoot long or I am going to shoot short of the technological possibilities. I need to understand what science is capable of delivering during the time frame of the requirement. With that input I can put a whole lot more rigor into designing the requirements. Work with me in designing those requirements. Come to these kinds of forums and listen to the vision, then be willing to say: We have technologies that could go in that direction.

What that means is that in addition to being who you are, whether you're a scientists or an engineer or designer or wherever your role in this business, you have to also become a marketer. This means that you have to be at the trade show. You have to be doing the show-and-tell. You have to patiently show us what this technology or science is that you are working on. Now, don't misconstrue that to mean that I don't want to buy your product. I want you to focus on my requirements and not your product. That is a major change. People like me tend to focus on products. I want you to patiently listen to my vision, give me some realistic technological boundaries, help keep me aimed at success and stay on target with what is possible. Let's work together as a team.

The next piece of this is the organizational commitment. This is much more difficult, although it is simply called resourcing. In today's environment resourcing is being tied very directly and precisely to analysis. As the technology becomes available, we need to understand the ramifications and implications of that technology. This is very important. If you have a new technology and you can't tell me what ramifications come with it, then we are already way behind the eight-ball, because we will be asked to justify our acquisition plans. I also need to know the ramifications of not accepting the technology. For example, there may be technology out there that you know that the Air Force has already decided to move into. I am in the Marine Corps and I may discover this too late in the process. I need you to tell me ahead of time that the Air Force has made some decisions. Does that make you a kind of extension to my staff? Maybe it does.

In terms of 'resourcing', when a new product comes in I would also like to see the amortization of that product. Are there going to be some related savings? Perhaps I no longer need three people or this building or this other technology and I can take those off the books. This is very



important, because I hear over and over again: “We can’t afford it, it’s just too expensive.” I need to know when I am going to receive a return on my investment.

Now why am I asking you to do this? Please think about this for just a second. I don’t want to demean any of the Marines in this audience. We have some very bright guys in here. You are very smart, you have gotten some advanced degrees, and you do a wonderful job. However, you truly are the exceptions. You are the scientists, engineers and designers in this world. I want you to stop and think for a moment about our Marine Corps, which is a very simple organization. The Marine Corps is not at all ‘high tech’. We don’t recruit from MIT, we probably have very few Marines who come from fair schools, and we don’t recruit from monasteries for sure. If you look at that population then you have to agree that they are not going to do this analysis. I mean, higher mathematics to a Marine means “... add 100 and fire for effect”. We need some help. I see some Marine faces in here who I know are very competent, but for the most part most of us that get assigned to these tasks have a tough time dealing with the analysis part. Very few truly understand what life cycle costs are all about. However, industry has a good grip on answers to questions such as: What does it cost for me to make do with what I have now? What will it cost me to do with what you propose? It is a simple comparison, but essential for our acquisition process.

So, now I have given you two solutions. I have said that if you will help me design the requirements and if you will help me with the analysis to present the case, then we can better accept the emerging technology. I would like to give you an example based on a vision for a command and control (C2) capability that leverages the advantages of intelligent agent technology. I am going to place this in the context of a very fluid, dynamic and widely dispersed battlefield, where information is abundant but not coalesced. Not unlike a blind man riding a motorcycle in New York City traffic and going very fast. The motorcyclist has all kinds of sensory input coming in, but doesn’t really have a clue that he is about to hit a bus. In many respects that is what is happening to us in this very dynamic environment. We need all that data to come in and to be somehow related. We need all of the databases that are out there to work with each other and we need access to them. However, that does not mean that we are going to redesign those databases or connect the files, or better still design and implement millions and millions of dollars worth of translators. Recently a company briefed us and said that to pull together fewer than two dozen very complex systems would take about 200 million lines of code. They had to scrape me off the deck; - 200 million lines of code at an estimated cost of \$10,000 to \$15,000 dollars per year per line to maintain? I am surprised that they had the courage to even tell me about such a software solution. I know that those databases are important and that we have to have access to them, but let’s not try to pull them together with 200 million lines of code. What we need is data in context so that software agents can automatically reason about the data. This would give us an incredibly fast staff of agents that can find us the right information at the right time. Then the same or other agents with different expertise and reasoning capabilities can quickly make some reasoned judgments and recommendations, in collaboration with each other and the human decision makers.

Let me tell you a little story. It’s time for a short break, in any case. I ride the train every morning, because I hate traffic and I have no patience so it is best if I sit on the train and protect the public from my terrible driving. So one day a priest is sitting opposite me on the train. A little



disheveled, kind of nasty, vile rodent of a human being sits down beside him. This little rodent digs out his newspaper and he starts thumbing through it probably just pretending to read. He starts a conversation with the priest and says: "Father, what causes arthritis?" The priest hesitates to respond, thinking that he really does not want to talk to this guy at all. He is disgusted by his apparent condition. But then he decides to teach the man a lesson. He replies: "Arthritis is caused by living a life of bad habits... booze, loose women, late hours... no job, no bath. The little man simply says "hmm, oh." A few minutes pass and the priest starts to feel really guilty about his reply. He thinks, I'm a priest I shouldn't be like that and, in any case, I kind of stretched the truth. God would not have liked my response. So, he turns to the man and says: "Please forgive me for that response, that was very cruel. How long have you had arthritis my son?" The vile little man folds his paper and says: "No I don't have it. I was just reading here that the Pope does."

You always have to have a context. I can envision a battlefield right now. It is crystal clear in my mind. As a commander I can view information that is tailored for me. I can tailor it from a handheld device to a multi-screen theater. The system knows my personal profile and my personal preferences. I know that I'll want my weather radar showing, so I tune it up for myself. When my Executive Officer comes in and sits down at the terminal, he just hits his button and the system is instantly tailored for him. I want to be able to adjust those thresholds that I talked about earlier. I want to be able to tell that machine just what I tell my Operations Officer, or the Watch Officer. Before I head back to get some sleep, I will tell him to wake me up for only five things. All commanders need this capability. I want the system to be able to do that and I want the system to know that it can take action with my blessing on certain things. I want the system to give me recommendations and I want to be able to authorize the system to take action, in the same way that I as a commander would authorize the Watch Officer to do certain things. What I'm saying is that the system has to be very tailorable. I want new options for decisions that are based on the dynamics of the battlefield such as the weather, the enemy situation, the operational successes or failures that are going on hour by hour, logistics, strengths, or potential weaknesses that I cannot quickly detect because of all the information that is coming to me. For example, a convoy has been dispatched after several hours of preparation to get it loaded, get everybody briefed up, get the overhead secured, arrange for the helicopter escort, and coordinate everything to ensure the safety of the convoy. It is on the road and some new information comes in regarding significant weather changes or enemy situations that could impede the mission. I am sitting in a Command Post (CP) right now and the system allows me to quickly assess the situation and reroute the convoy. Consider the opportunity costs of simply rerouting the convoy safely around the problem area. What are the implications on delivery times? What are the implications on equipment matching. The new route may not be able to handle that size truck. There may be a really important trailer load 10 miles up along the original route that is waiting for a tractor in this convoy. I cannot think of all those things on the fly, there is too much else going on. Therefore, I want the system to do those kinds of things. That is what I mean by dynamic decision making.

I want a user-interface screen that offers the capability to be entirely collaborative, at the tactical level, at the operational level, and at the strategic level. I want to be able to go from tactical to operational at the strategic level, to operational to tactical between the services. I want the levels of staff and command authority to be delegated by me according to my personal style. Let's go



back to for a moment to the weather example. You know we have meteorologists and equipment with us to provide us with very local weather information. We can also get regional and global forecasts, so we do have access to a fair bit of weather information. However, that is not the same as having a system that is continuously looking at all of the meteorological data, including the two-week global prediction of sand storms. Such a system can very quickly tie several factors together, access a regional map, and warn me that the wind is really moving to the north by a long shot even though my local data suggests that the dust storm is not even close to us. All of this has a significant impact on my operational plans for the next 24 hours and I can do much of that now with my weather reports. What I cannot do is to determine the implications on my operations three days from now. Also, I cannot predict the implications if I decide to launch right now. What does that do to my logistics considerations? Those are very difficult to plan if you speed up that much. So, I want the system to collect the current conditions, the enemy situation, the weather, and many other pertinent factors. Then I want the system to reason about all of this information on a continuous basis and give me conclusions and recommendations.

What if current operations change? This happens all the time. We may have a success that needs to be exploited or a failure that needs to be corrected. Many alternatives have to be evaluated quickly and countless decisions have to be made. It goes beyond the combat operations center to all of the support folks and their decisions. This is where it becomes encumbered and difficult. The agents in my hypothetical system may come back with the recommendation to slow down the convoy to 10 miles an hour so that we don't bunch up. The system can do that for us after it has reasoned on variables such as the weather and the road conditions. A success in the operational scene can bring another re-supply opportunity. For example, we have had a success on the left flank. The system can quickly look at the variables and say that we could re-supply right now, to avoid a weather that is coming our way. In other words, the system alerts the commander to a window of opportunity that is more than likely to have been missed under the deluge of data.

Now, if this vision of the C2 world does not challenge you or make you think a little then let me know, because I can dream some more and I am more than willing to do so. If what I have thought of is not acceptable to the user, then you and I have to work together to help change the way that the user thinks about this. It can't be just speed and a prettier display on the screen. That wraps up what I wanted to share with you this morning. Thank you for your patient attention and for the opportunity to present my vision to you. I believe there is time for a few questions.

***Question:*** *In addressing the issue of the culture change, it occurs to me that one of the biggest impediments is going to be the testing community who have to be able to answer satisfactorily for the operational commanders... whether or not garbage in equals truth out or garbage in equals truthful garbage out... or we have truth in and truth out, and that's a significant issue in the Hal counterculture. Are you making any inroads on the testing community or is that still an area that needs to be cultivated?*

Like all of them, that is an area that desperately needs to be cultivated. In fact that was one of the issues that General Mattis brought up to me when he talked about the reliability of computer-based systems. I was actually in Iraq with him when he told me this and so he was still pretty emotional about it. He said what you're talking about here is intriguing, but I have no confidence



that we're not putting garbage in and that I am not going to get garbage out. Then I am going to make decisions on Marines' lives based on such information. We have to make some assumptions that the data that's coming in is correct. Do we have any pilots in here, but you can't fly an airplane if you don't have some trust that the data that's coming in is correct. I think we can make people like General Mattis and the testing community more comfortable with those assumptions if we put a mechanism in there that occasionally looks at the data and tells us that it is within some kind of zone of reliability. If you have a scared corporal out there and you ask him to count the number of tanks and he sticks his head over the wall as the rounds are coming at him, then he is going to come back and say "... a bunch". That is not real precise data to work from if you are doing precision targeting.

**Question:** *My basic question goes the other way. The Marine Corps is working on how to use the AAV. How are your dreams or requirements getting into the AAV and into the expeditionary force?*

Well, as far as the AAV is concerned, those who know me know that is probably a bad example. What we are looking at is autonomic logistics. One of the difficulties we have had with that are feeds. There is just too much information to get through the pipes. I was down at Oakridge and they showed me this phenomenal technology. It takes away the requirement to have a constant transmission of data from sensors. Instead it measures electric pulses in a predictive manner. This is what the Air Force uses now. You place these clips on different parts of the airplane at incremental points in the life of the aircraft, for example after every 100 hours of flight or something like that. Based on the measurement and interpretation of electric pulses the software can make some determination that there is a bad bearing or that something is not running up to speed. What is important is that you don't need to transmit data constantly. You just need to take a look at the data that comes in during periodic checks to be able to predict a future failure. I would suggest that as far as the AAV is concerned, we want to go in that direction.

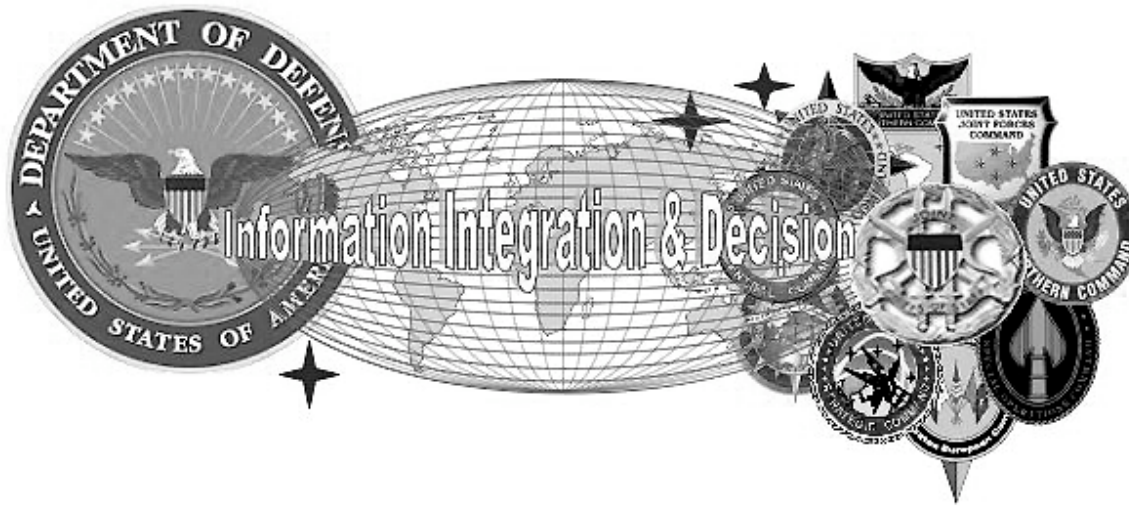
In respect to the expeditionary force, we are dealing with something quite different. The dispersed battlefield is not really a new idea. We probably used dispersed operations unintentionally during World War II and we certainly used them intentionally in Vietnam. However, we did not have all of the capabilities that we have right now. A dispersed battlefield in the future means that we are going to have one squad 20 miles out here, another squad 20 miles out there, and a platoon 40 miles out over here. We have to know what they are going to do today, tomorrow and the day after, and what their requirements are going to be and how we can get them back together again. Right now all we really have is a radio, and that is not enough. We also need to have some decision-support.

Thank you very much.



## Information Integration and Decision *A Strategic Approach for Interoperability*

Mr. Don Diggs  
Director C2 Policy, OASD(NII)



In the read ahead provided on this conference, it was noted that the “theme” was interoperability. Topics identified included: Homeland Security, GIG architecture, multilateral and coalition interoperability, taxonomies and ontologies, and government plans and initiatives. While I’m not an expert on any one of these areas, I hope in the following minutes I can provide an overarching context to the approach DoD is taking toward interoperability as well as provide an example of how we may want to “field” capabilities in the future.

Whenever I hear the words ontology and taxonomy I think of the word **Secure**. It is an old joke but it’s said that one reason the Services have trouble operating jointly is that they don’t speak the same language. For example, if you told **Navy** personnel to “secure a building,” they would turn off the lights and lock the doors. **Army** personnel would occupy the building so no one could enter. **Marines** would assault the building, capture it, and defend it with suppressive fire and close combat. The **Air Force**, on the other hand, would take out a three-year lease with an option to buy.

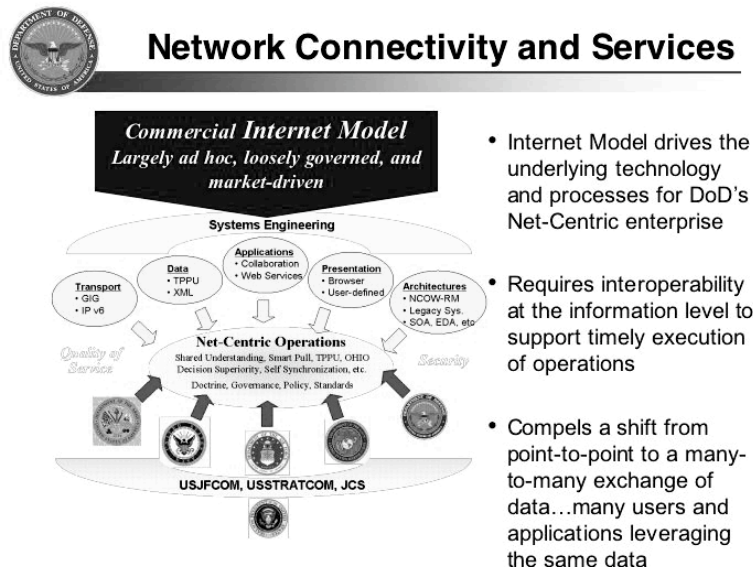
Now if you think of the word “tank” in the same context, it becomes apparent that we have much to do in breaking down the language barriers that will allow net-centricity. We need to move toward net-centricity with an enterprise architecture. Don’t **even** ask me to define what architecture is, but it’s clear that as we charge ahead, and if we are to be interoperable, we need to work on the basics.

I am entitling this presentation Information Integration and Decision, and the reason I’m doing that is because we’re wrestling with the notion of domains today in the Department of Defense... one of the domains is the C2 domain. There are a lot of people that claim ownership of that C2 domain; in fact the real owner of C2 is the warfighter. OSD NII (Networks and Information Integration) is the Principal Staff Assistant for C2. That doesn’t mean NII is doing C2... we are



not doing the functions of C2 nor do we specify what those functions are, BUT we need to be able to provide an integrated information capability much along the line that General Lott described. We need to support decision-making with C2 services and applications tools.

## Network Connectivity and Services



I am going to talk a little bit about data and the importance of data. It is not that there is too much data out there, but there are two problems: we don't know how to handle the data appropriately and we don't have a common data structure. I will talk more to this, but a good example is UAVs ... we fly UAVs over in Afghanistan all the time, usually they are targeted on a specific area on a specific day on a specific mission. The problem is that they are always filming, always taking pictures on their way in and on their way out. It is very likely that these UAVs are going over a target rich environment for somebody who doesn't even know the UAVs are flying. The information the UAVs see may fulfill a future need for someone who doesn't even know that he needs the information on that area until several days later. How do we capture that data, but still make sure it does not overload the system and get it to the warfighters when they need it?

Frank Coyle has a book out I recommend reading if you haven't already. In his book "XML, Web Services, and the Data Revolution," he notes how the Web and data description technology known as XML have initiated fundamental changes to networks by shifting the focus from tightly coupled computing environments to loosely coupled networks centered around the Web and XML. The effect, he notes, has spawned three revolutions.

- The first, the data revolution, is the story of XML and its impact on how to represent data.
- The second is about software architectures and the move to loosely coupled distributed systems.

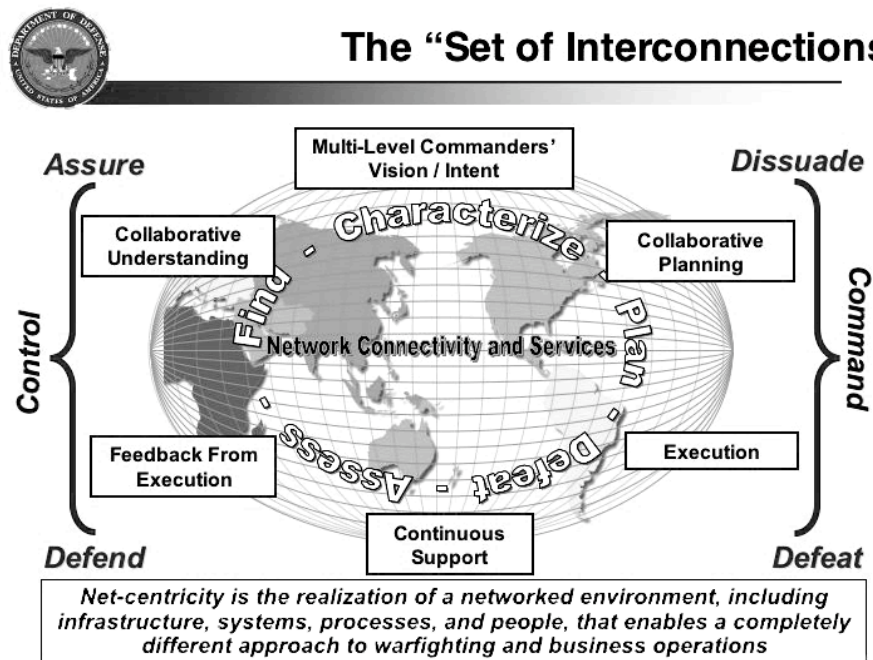


- The third, the software revolution, involves a changing model of software construction – software based on simplicity and modularity, rather than software that “does it all”.

This Internet Model drives the underlying technology and processes for the DoD Net-Centric enterprise. Further, it requires interoperability at the information level to support timely execution of operations and compels a shift from point-to-point to a many-to-many exchange of data... many users and applications leveraging the same data. What’s important is how we share data across the enterprise so that the warfighters who need the information can access it and use it in ways unique to their needs.

The point I want to make on this chart is that our approach forward to net centrality must reorient toward a market driven approach rather than from the top down. And more importantly, our acquisition processes that here-to-fore have been focused on the military departments and programmatic needs to be more adaptable to a more dynamic environment.

### The “Set of Interconnections”

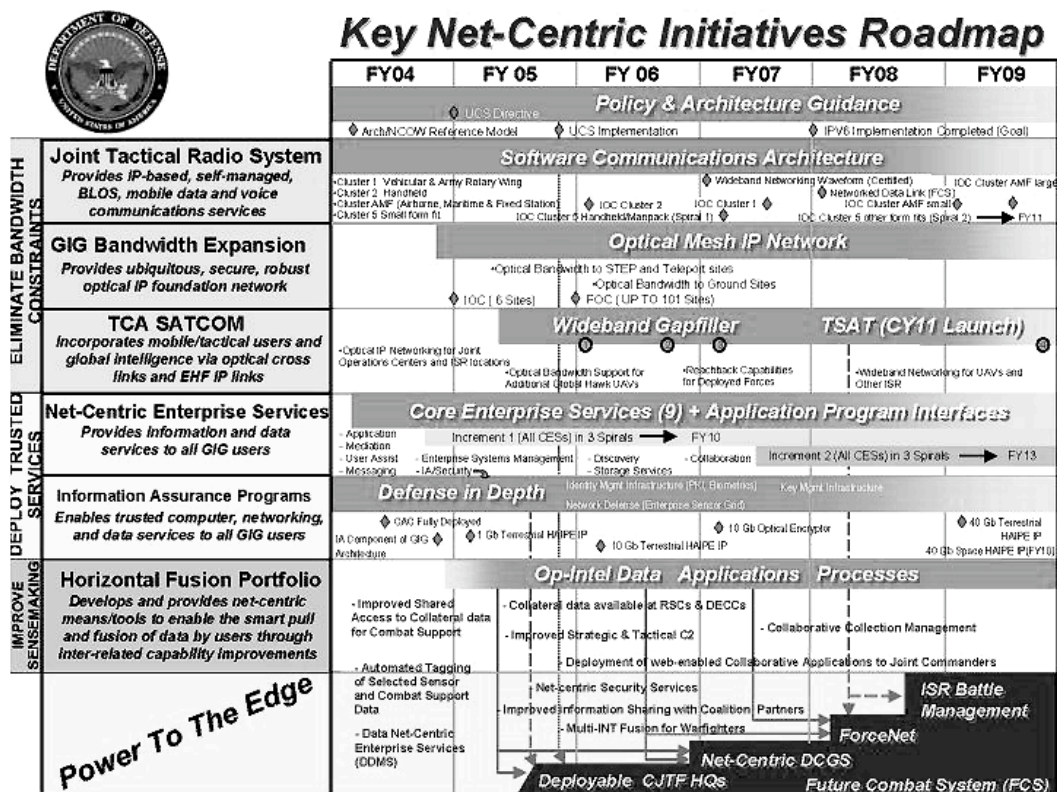


Another consideration is how we ensure the strategic goals specified in the last Quadrennial Defense Review, **ASSURE**, **DISSUADE**, **DEFEAT**, and **DEFEND**, shown around the outside four corners, can be achieved in a net-centric environment.

Certainly, those goals must be supported by a strong command and control capability represented by a set of processes as shown in the boxes around the globe. Those processes are supported by functions and capabilities. The question is how we map functions and capabilities to services and applications in an enterprise fashion that resides on a network and is supported by services and applications. That is the difficulty. How do we map functions to capabilities in what today is largely programs fielded in stovepipes. Building the GIG architecture is the first step.



## Key Net-Centric Initiatives Roadmap

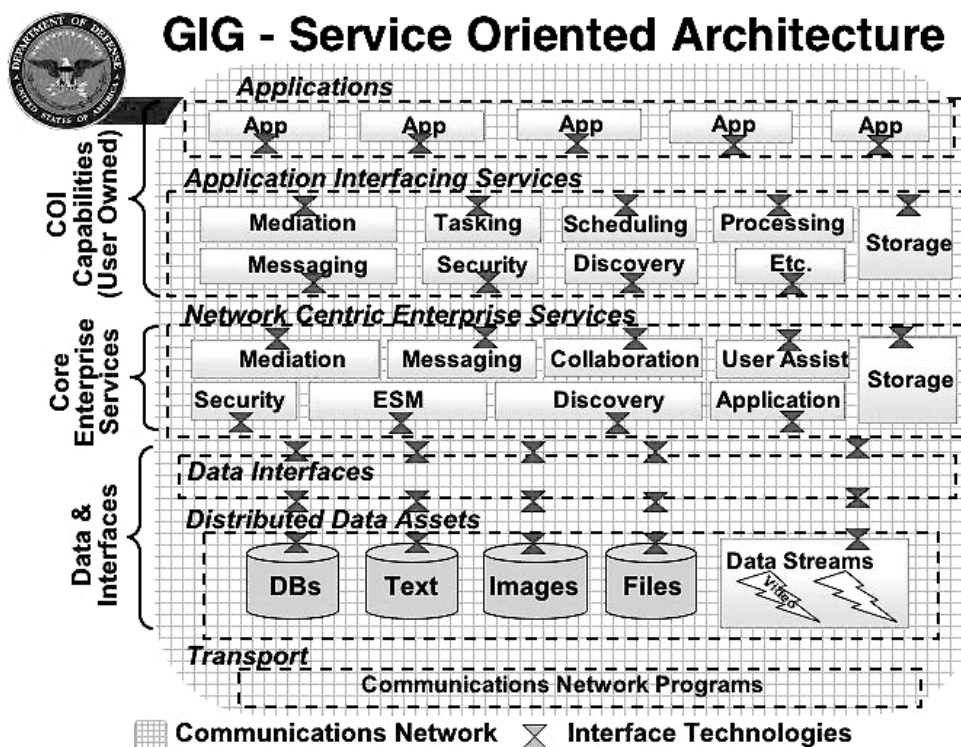


I promise not to linger on this slide, but it does address the DoD goals in implementing the GIG, which are threefold:

- Goal 1 is to build a trusted, dependable network,
- Goal 2 is to populate the network with accessible and usable data,
- Goal 3 is to protect the network from exploitation.

The graphic provides insight into Department's efforts to support these goals. I won't go into detail – that would be a whole other brief - but as indicated in the programs and initiatives on the left... the Joint Tactical Radio System, the GIG Bandwidth Expansion effort and the Transformational Communications Architecture Satellite Communications Systems... will allow the Department to reduce network bandwidth constraints. Net-Centric Services and Information Assurance efforts will allow employment of trusted services to users of the GIG. Lastly, our Horizontal Fusion Portfolio efforts will develop Net-Centric tools to enable smart pull and fusion of data by GIG users.





The traditional approach to interoperability has been the “system-of-systems” approach. **First**, true interoperability can only be achieved through data management, with the focus on the visibility and accessibility of data rather than just standardization of the data. Improving the flexibility in data exchange means interoperability between systems can be achieved without requiring predefined and node-to-node mapping of interfaces. **Second**, data becomes actionable information through applications and services. The services available on the network are either enterprise services (e.g., NCES) or developed and offered at the community level. The **Enterprise Services** provide basic computing capabilities to the Enterprise, for example, providing reliable identification and authorization services to assure the security of the data. Additionally, users and applications through enterprise services will be able to exploit easy to use search tools and software agents that allow them to search metadata catalogues and “pull” data from across the various communities and the Enterprise. And **third**, applications and services need to be supported through an architecture. The increased use of networked data capabilities requires a ubiquitous, high-speed, dependable communications infrastructure. Accordingly, the enterprise services will be deployed on the GIG and will leverage the expanded bandwidth and network availability provided by TCS, JTRS, and GIG-BE activities.

Finally, organization and maintenance of data is the responsibility of **Communities of Interest**, or COIs. COIs promote data posting, establishing “shared” space, and creating meta-data catalogues. Data can be exposed within the COI or across the Enterprise by having users and applications advertise their data assets by cataloging the associated metadata or the descriptive information about the meaning of data. Catalogues, which describe the data assets are available, are made visible and accessible for users and applications to search and pull data as needed.



The **goal** is increasing the data available to communities, or the enterprise, and ensuring that data is usable by both anticipated and unanticipated users and applications. Making the data visible, accessible, understandable, and trusted is the **key** to interoperability between systems.

## New Paradigm Challenges



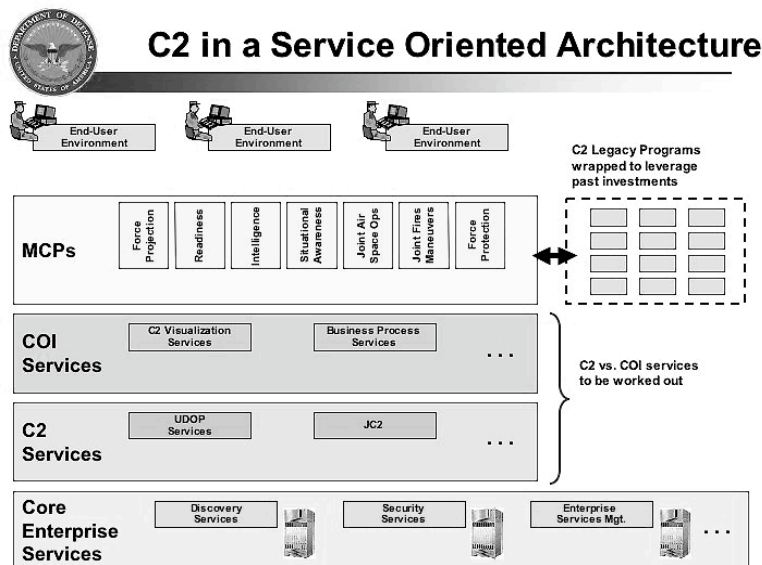
## New Paradigm Challenges

- Publish and Access
  - How, where and what do data resources publish?
  - How do users find and access resources?
  - How is data product or service delivery achieved?
- Context: Global Information Grid (GIG)
  - Massively networked environment
  - Many complex interconnections
  - Numerous, frequently changing data resources
  - Dynamic network architectures (e.g., crisis-specific)

This enterprise environment provides opportunities and challenges. For example, how and where do we publish data resources and then how do users access those resources? And, how do we assure delivery of data resources? Who is responsible for maintaining the data?

The GIG is a massively networked environment with many complex interconnections. It is highly dynamic. How we model the environment, understand domains, and operate COIs within the enterprise, for now, creates more questions than we have answers.

## C2 in a Service Oriented Architecture





NII is working with the Joint Staff and the various combatant commanders to place context toward this challenge. For example, if you were to view one of the Joint Staff domains, in this case C2, against the Mission Capability Packages or MCPs, in the context of a SOA, it might look like this.

DoD is just beginning to look at the decomposition of C2 services and applications that are available within programs of record to support the MCPs and to define how COIs support this effort.

### What is Required



## **What is Required**

- Develop / articulate DoD C2 policies for integrated, net-centric C2 capabilities
  - Drive changes to doctrine, concepts, and processes
  - Explore new implementation strategies
- Leverage network connectivity and web services to enhance information integration and decision-support to the warfighter
  - Achieve a seamless and ubiquitous command structure (national through tactical)
  - Ensure data is visible, available and usable which promotes interoperability through standardization of data elements
- Define a services oriented architecture (SOA) that allows for "interconnections" between the President, senior leaders, and warfighters that will meet critical C2 functions and decisions
  - Enhance senior decision-maker ability to dynamically collaborate
  - Improve Combatant Commanders execution of supported and supporting roles - globally and regionally
  - Enable agile C2 to the warfighter

So what is required.....

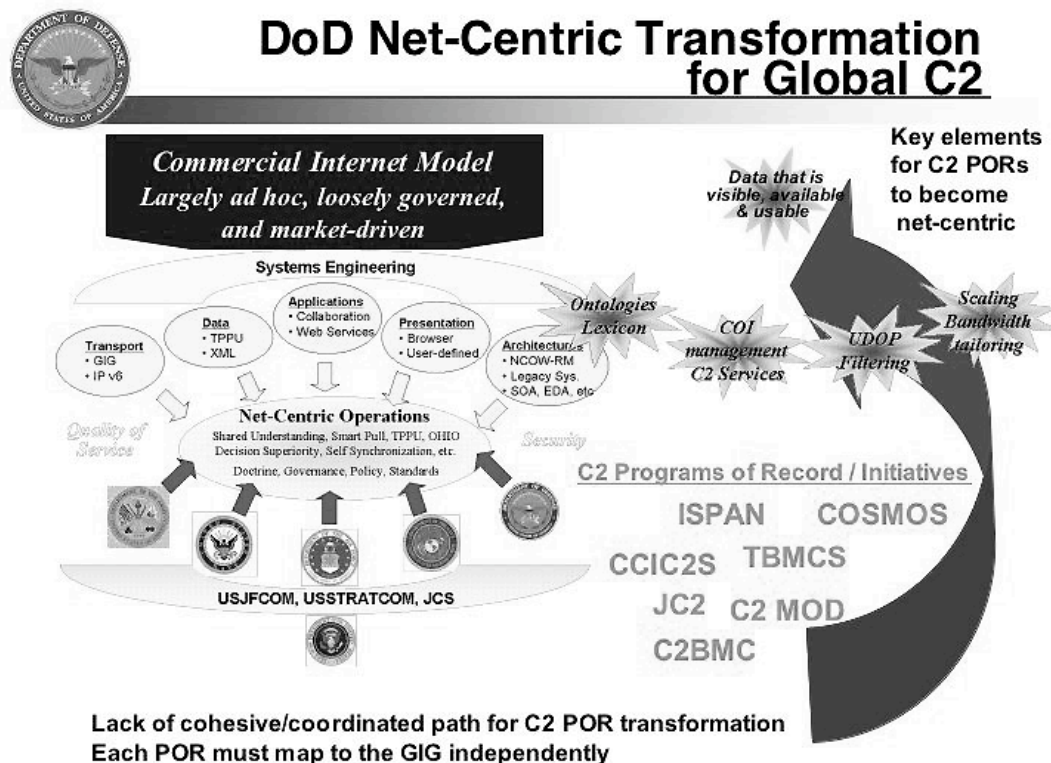
The DoD-wide C2 policy we currently have on the books is from 1972 and is titled Worldwide Military Command and Control System or WWMCCS. This policy has not been updated and needs to be.

We need to drive changes to doctrine, concepts and processes that address the things General Lott was talking about... things that he needs out in the field. These concepts are not going to happen without looking at new ways of fielding capabilities. It is very difficult to meet the needs of what the General wants the way our acquisition system is structured today. We need to explore new implementation strategies that leverage network and web-based services and allow broader access and use of authoritative data. There are ways within the construct of what we have today to implement some of the services and applications in a Service Oriented Architecture in which connectivity and web services can enhance information integration and decision support.



Again, we need to ensure that the data is visible available and usable and, I keep going back to that because I think it is one of the basics that we haven't gotten right. People are still going out and fielding services and applications program by program with the dissimilar ontologies and taxonomies and with data that can't be used by other programs. A good example is the Combatant Commanders Integrated Command and Control System (CCIC2S). It provides intelligence, indications and warning, and attack assessment for NORAD. A lot of good data resides in CCIC2S that is used by applications and services specific to NORAD for missile warning, space operations and the like. Unfortunately, as we move forward with missile defense some of the data MDA needs, particularly at the sensor level, resides in CCIC2S which for certification reasons cannot currently be shared. Similarly, MDA systems will generate data that CCIC2S can use for Integrated Tactical Warning and Attack Assessment but can not directly access. As a result decision makers wind up with separate operational pictures for missile warning and missile defense which they then have to integrate mentally. This is a problem we can solve through an SOA approach to allow interconnections between the President, senior leaders and warfighters and create user defined operational pictures that will dynamically change how we operate and achieve agile command and control.

## DoD Net-Centric Transformation for Global C2



As we've discussed before, DoD is being driven by the commercial internet model that is ad hoc, loosely governed and market driven. This model is really what is pushing net centric operations. The question is, what do we do with current programs of record, many that are legacy, but that



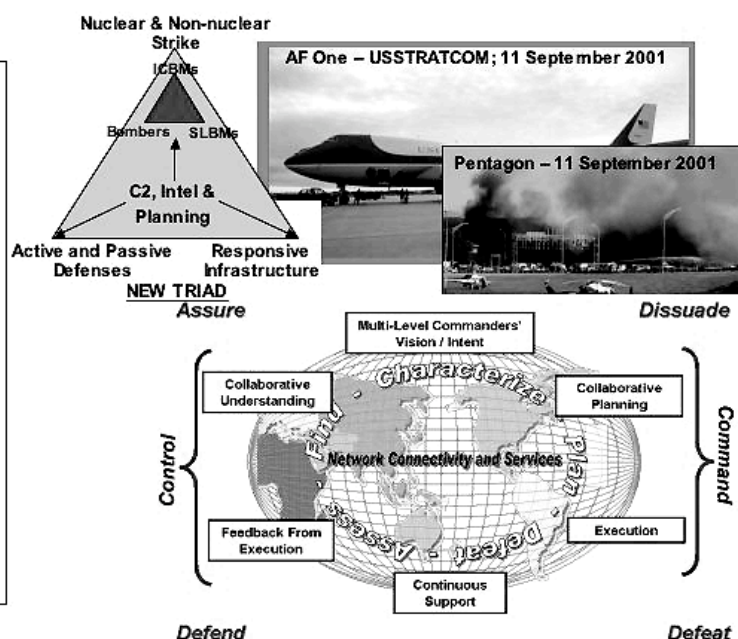
still have significant dollars, and, more importantly, authoritative data attached to them. Currently, we do not have a coordinated path for how to take programs into this net-centric environment. We should be able to move now on some of these programs to encourage them to adopt key net-centric elements such as defining domain ontologies and taxonomies, and ensuring their data is visible, available, and usable as well as exposing services and applications to the network. Today, we do not have a cohesive path for doing this – each program must map to the GIG independently.

## C2 Gaps & Challenges



## C2 Gaps & Challenges

- Gaps in Strategic, Global & National C2 capabilities
- Dynamic security environment
- NPR, UCP, NSPD-28 require enhanced C2 capabilities
- Large investments in legacy systems with authoritative data



One reason we need to move rapidly into the net-centric environment is to address the gaps and challenges we have in C2 today. I don't think it is a surprise that we have significant gaps in Strategic, Global and National C2 capabilities. 9/11 exposed many of these gaps and this was largely a result of having fielded programs supporting national-level C2 in a stove-piped fashion.

In addition to this dynamic security environment there is new high-level guidance such as the Nuclear Posture Review, the Unified Command Plan, and other Presidential directives that require DoD have enhanced Command and Control capabilities. The NPR was really a strategic posture review that redefined the old nuclear TRIAD into a New TRIAD consisting of nuclear and non-nuclear forces, active and passive defenses and a responsive infrastructure to achieve the nation's strategic goals. To achieve the resulting strategic capabilities and accomplish these new missions means that DoD must take a new approach toward C2, intelligence and planning capabilities.



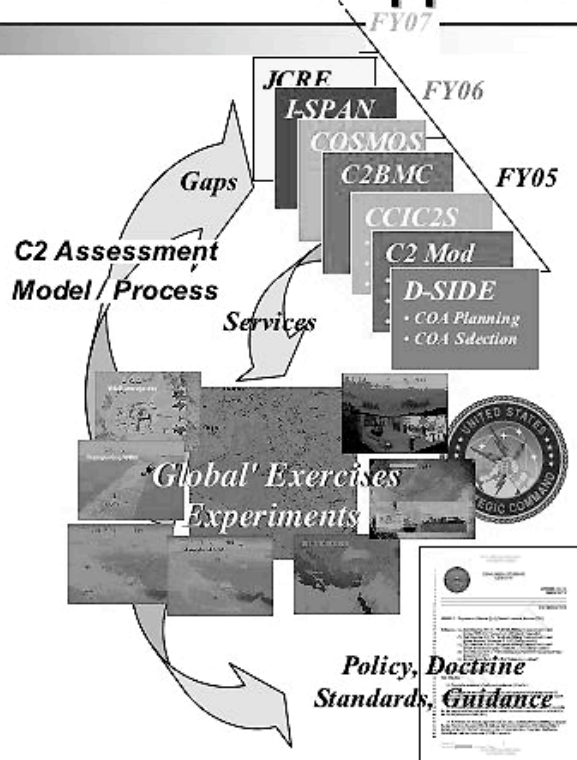
Again, the question is, how do we transform legacy C2 programs, some where we have a very large investment, and expose their data and services to the network.

## A Portfolio Approach



## A Portfolio Approach

- Define global C2 capabilities required for strategic reference mission(s) & scenarios
- Establish a 'portfolio' of services from existing C2 programs of record that fulfill defined capabilities
  - 4 Shifts focus from programs/platforms to capabilities
  - 4 Reduces operational, future, force management and institutional risks of Global C2 implementation
- Leverage Net-Centric initiatives (e.g. GIG, NCES)
- Capture portfolio lessons into guidance, policy, doctrine, standards for broader domain application
- Requires strong warfighter support to advocate and support portfolio efforts



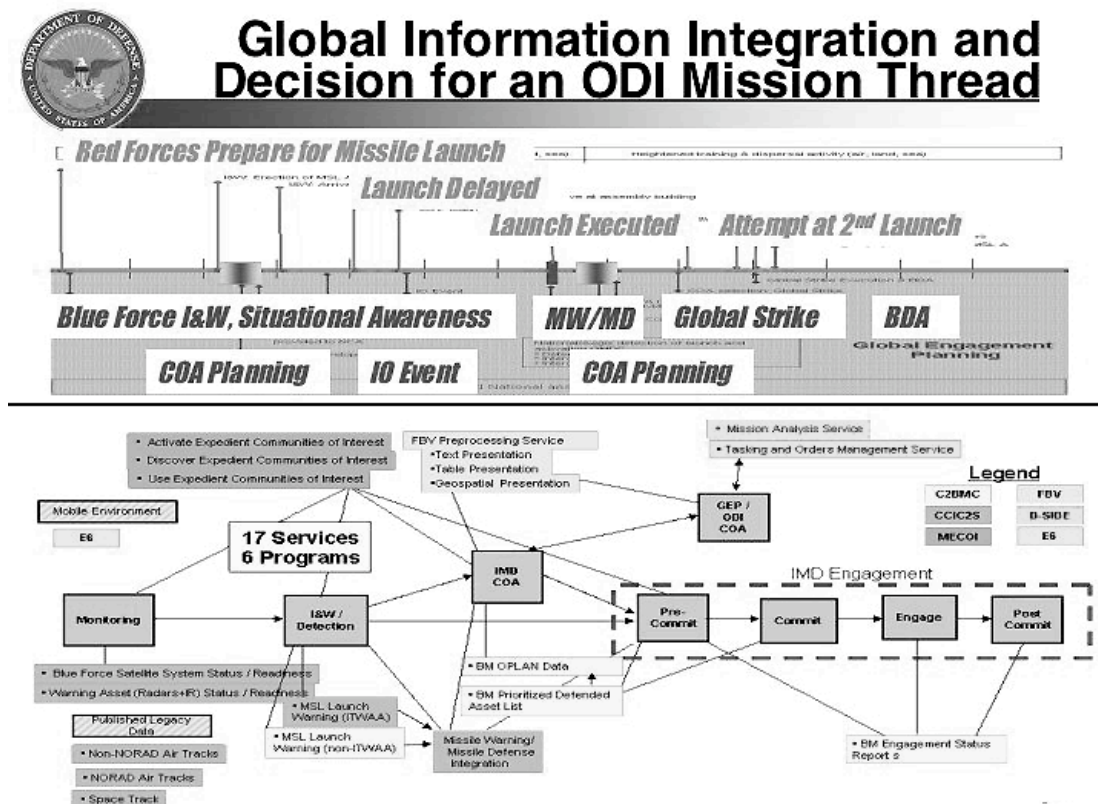
One approach is to use portfolio management. A portfolio approach may be that we define the global C2 capabilities required for strategic reference mission(s) and scenarios. Then, we can establish a 'portfolio' of services and applications from existing C2 programs of record that fulfill our defined capabilities. The result of such an approach is a shift in focus from programs/platforms to capabilities and to data and services. By leveraging Net-Centric initiatives (for example Net-Centric Enterprise Services) we should also be able to reduce infrastructure costs to current programs of record.

With success, we can then capture portfolio lessons into guidance, policy, doctrine, standards for broader domain applications. Such an approach will require strong warfighter advocacy and will challenge current organizational boundaries.

I'd like to walk through an example of how, from capabilities, one might begin to identify services and applications of importance and help us focus on important data sources.



## Global Information Integration and Decision for an ODI Mission Thread



This looks complicated until you break the code.... essentially we are looking to fill capability gaps.

The example here uses a specific mission thread, in this case offensive-defensive integration, as a way to define the capabilities and services that must be present and then maps the services available through various programs and initiatives that can support this mission thread.

In this way we can determine where programs provide like or similar services, showing where a “best of breed” selection can or should occur and also where the deficiencies or gaps in capability are.



## Representative GIID Portfolio Services



## Representative GIID Portfolio Services

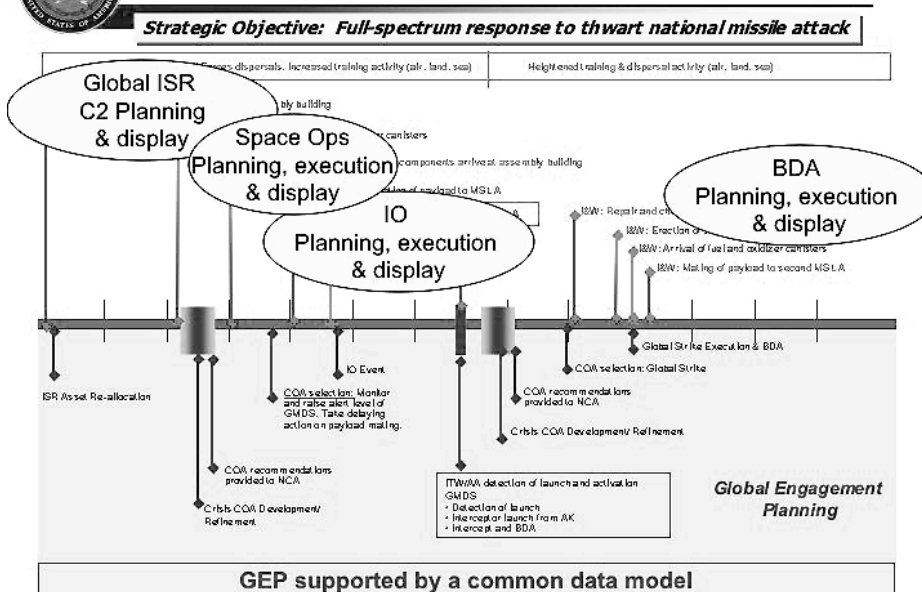
Program	Service
CCIC2S	Blue Force Satellite Status and Readiness
	Warning Asset (Radars & IR) Status and Readiness
	NORAD Air Tracks
	Missile Launch Warning (ITWAA)
	Space Tracks
	Non-NORAD Air Tracks
	Missile Warning / Missile Defense Integration
C2BMC	Missile Launch Warning (Non-ITWAA)
	Ballistic Missile Operational Plan Data
	Ballistic Missile Engagement Status Reports
	Ballistic Missile Prioritized Defended Asset List
D-SIDE	Mission Analysis Service
	Tasking and Orders Management Service
FBV-C2Mod	Text, Table, and Geospatial display for MARS Portal
ECOI	Activate Expedient Communities of Interest
	Discover Expedient Communities of Interest
	Use Expedient Communities of Interest

These services were originally developed based on unique system requirements for two stovepipe programs, missile warning and missile defense. These services can not effectively provide an integrated missile defense picture that supports both offensive and defensive responses to the same event unless the programs are redirected and/or incentivized to publish their data and expose the identified services to the network, and to each other.

## GIID Portfolio Gaps



## GIID Portfolio Gaps





After filling one gap, future spirals are directed toward filling other gaps that are part of the same mission thread... as net-centric services are fielded filling a gap in one mission area will also fulfill gaps in other mission areas resulting in spirals that cut across mission threads as well as focus on a given mission thread.

#### Prospective follow-up GIID Portfolio ODI Mission Service List



## Prospective follow-up GIID Portfolio ODI Mission Service List

<div>CCICCS</div> <div>ISPAN</div>	Blue Force Satellite Status / Readiness	CZBMC	Missile Launch Warning - (Non-ITWAA)	TBMCs	Mission Details Service
	R/G Force Satellite Status / Readiness		Ballistic Missile Track Reports		Air Tasking Order Generation (file)
	Warning Asset (Radars + IR) Status & Readiness		BM Threatened Asset Reports		ATO Selected Elements
	NORAD Air Tracks		BM C&P Data- Red Force		Air Control / Coordination Order Generation (file)
	Satellite Footprint/Coverage (Overflight)		BMDS Weapons C&P Data		ACO Selected Elements
	Enemy Ballistic Missile OOB		BM OPLAN data		Strategy Management Service
	Enemy Satellite OOB		BM ADP data		Airspace Usage View
	Space Tasking Order		BM Defense Design Data		Enemy Air Order of Battle
	Threats to National Space Assets		BM Candidate Target Nomination Lists		Enemy Anti-Aircraft Order of Battle
	Threats to National Land Sensors		Red BM OOB Update		Global Strike Asset Availability/Suitability Service
	Threat from Ballistic Missiles to North America	FBV/C2/MOD	Blue BMD Asset update	D-SIDE	Mission Analysis Service
	Threat from Ballistic Missiles to Theaters		BM Engagement Status Reports		Tasking and Order Mgt. Service
	Missile Launch Warning - (ITWAA)		Projected interceptor tracks		Execution Mgt. Service
	Missile Launch Warning - (Non-ITWAA)		BM Prioritized Defended Asset List		Identification of expedient community
	GPS NAV Accuracy		Strategic Force Status and Location		ECOI business rules and roles
	Space Tracks		Strategic Force Readiness		Coalition NBC Event Notification
	Non NORAD Air Tracks		Base Posture		Coalition Tracks
	Missile Warning/Missile Defense Integration		Text Display service		Coalition Interdiction Candidates
	National Target Base		Table Display service		Coalition NBC Event BDA
	NATP mission data		Geospatial display service	COSMOS	
	Unit mission data (bomber, tanker, ICBM, SLBM, Recce, TLAM)		Timeline display service		
	Analysis: CofE, PA, PD, PTP		Image display service		
	Theater mission data				

**Focus for FY06 -- add Integrated Space Operations Planning, Execution and Display capability**  
(highlighted items reflect candidate services)

In this case the identification of additional services and applications is needed to address the gap in integrated space situational awareness. The portfolio approach, therefore, allows us to gradually evolve net-centric services within and across mission areas by not focusing on stovepiped programs but by looking at how services and applications within these programs can be identified to fill capability gaps.





## Challenges to Interoperability

- Achieving transparency in mission and domain governance
- Avoiding the desire for the 100% solution
  - Recognize the "Network" as a loosely-coupled and dynamic "mega-system"
  - Less focus on a "grand design" and accept "complexity"
- Optimizing the network by shifting focus from individual C2 programs and / or missions to C2 capabilities enabled by C2 services / applications.
- Breaking down the "organizational" boundaries in:

Objectives  
Management  
Funding

The challenges to achieving net-centric interoperability are many.

The first is in the area of governance. Experience shows that governance is required to set the rules that determine how a mission area will function and define or develop the services and data needed within that domain. However, putting governance in place for this new transformational environment is difficult to achieve because it transcends the organizational rice bowls we have had in place for some time. One approach is to look at governance as a function of COIs and let COIs define services and data strategies for the missions they are created to accomplish.

A second challenge is the natural desire to find a 100% solution and having all the answers in hand before moving forward. We need to recognize that the network is going to be a loosely coupled, dynamic mega-system, not tightly coupled applications and communications that provide point to point connections as in the past. It is important to focus less on the grand design of what we are building and accept and adapt to the complexities involved.

Finally, I think we need to optimize the network by shifting the focus from individual C2 programs and missions to C2 capabilities enabled by services and applications. To do so requires changes in the organizational structure to allow new ways of developing service oriented capabilities and allow data to be shared across traditional organization boundaries. This applies to how we fund programs as well. In the future we need to think in terms of how programs can leverage applications, services and data from other programs within the net-centric environment and fund only those applications and services that are unique. Funds can then be redirected toward filling capability gaps as they are identified.





## Summary – What is needed

- A cohesive path forward
  - Adopt a Services Oriented Architecture (SOA) strategy for deployment of capabilities
  - Understand interactions that must be established to field an SOA through existing DoD processes (JCIDS, Acquisition, PPBE)
  - Put backbone into data strategy and begin the domain grunt work – establish requirements, taxonomies, data structures, etc.
- Clear / unambiguous leadership and strategic direction
  - Roles and responsibilities need to be defined
  - Organizational boundaries need to be overcome - objectives, management and funding

In summary, what is required is a cohesive path forward. Clearly the Department of Defense is moving forward with the development of the network; the GIG. It remains a challenge to move from a programs and platforms oriented acquisition approach to a data centric approach, supported by a services oriented architecture strategy for deployment of capabilities.

It is also clear that while we need to work through existing DoD processes, specifically JCIDS, acquisition, and PPBE, the interactions between these processes and fielding net-centric capabilities remain a challenge. Roles and responsibilities need to be defined and organizational boundaries need to be overcome in the area of management and funding.

Mostly we need to begin to put backbone into data strategy and start the domain grunt work – establish requirements, taxonomies and ontologies, and define data structures.

We need a path forward.





## Path Forward

- Establish strategic leadership and a “DoD Enterprise View” for C2 across global and regional net-centric infrastructures
  - Consider creating a “C2 Committee of Principals”
- Manage deployment of C2 capabilities through a portfolio strategy and resulting technical architecture
- Pace the evolving National Security and Military Strategy (i.e. avoid C2 as a limiting factor) by driving the Network to support C2 capabilities across the threat spectrum
- Put backbone into domain initiatives that are languishing
  - Adopt a Services Oriented Architecture (SOA) strategy for deployment of capabilities
  - Support through existing DoD processes (JCIDS, Acquisition, PPBE)
  - Begin the domain grunt work – establish requirements, taxonomies, data structures, etc.

These are the things we need to do to achieve true interoperability within the DoD as we move into the next budget cycle and these are the things that I have talked about as necessary to achieve the C2 capabilities needed to support our leaders and warfighters as we transform to meet future challenges.

### DoD Transformation





## DoD Transformation

---

Network-centric transformation is working

- The information revolution is transforming our society and the way we live. It is transforming the Department of Defense
- DoD is leveraging these capabilities to transform the Department by creating interoperability at the data level and enabling Network-Centric operations
- The benefits of these changes are being shown daily in Iraq, Afghanistan, and elsewhere. They are improving military capability and saving the lives of our troops daily
- DoD's network-centric initiatives are delivering on their promises. The pace of change is accelerating and will have an increasing positive impact on the Department's future

In conclusion, Net-Centric transformation is working. The information revolution is transforming our society and the way we live and DoD is creating interoperability at the data level and enabling Net-Centric operations. The benefits of these changes are being shown daily in Iraq, Afghanistan, and elsewhere. They are improving military capability. DoD's Net-Centric initiatives are delivering on their promises and will have an increasing positive impact on the Department's future.

Thank you for your time. Are there any questions?







**Coalition Secure Management and Operations System (COSMOS)**  
*A Role-Based Access and Privilege Model for Coalition WAN Operations*

6<sup>th</sup> Annual Office of Naval Research Conference  
9 Sept 2004

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## COSMOS Orientation

*Viewing war as art rather than science*

- Problem of complexity
- Role of chance
- Prompting of intuition
- Question of form

Slide 2

Today I'll be talking about Art and its value as an approach to addressing large complex problems. The COSMOS ACTD proposes to address a large and complex problem, the challenge of integrating coalition C3 networks, and of sharing information across boundaries.

I will be talking about these themes in the context of network design and efficient sharing of information. They are the reason that war is an art form and not a science. They apply to all aspects of war and not just the business of C3, but I suggest that they have a particular relevance to Net-Centric warfare. And although we often speak of the art of war, we do little to prepare ourselves to operate in the realm of war, which is the realm of art rather than science.



The COSMOS ACTD will introduce us to Net-Centric operations squarely situated in the realm of art. And I believe it will offer us valuable insight, not only into how to better share information with our allies, but more importantly, on how best to design, manage, and fight the GIG.

## Ideas on the Nature of Art

### Aristotle:

"All art is concerned with coming into being, with considering and contriving how something may come into being."

"Art loves chance, and chance loves art."

### Dante:

No artistic expression is possible without constraint, "the Curb of Art."

### Hegel:

"Architecture levels a space for the concentration of spirit and for its direction to the mind's absolute objects."

### Slide 3

Here are some ideas on the nature of art that I ask you to keep in mind as we go through this briefing. Art has always been man's way of reconciling reality with the ideal. Our rational capacity permits us to glimpse perfection, and yet our capacity for reason tells us that it will always remain beyond our grasp. It is in reconciling the dynamic tension between what is and what might be that man's creative powers are summoned.

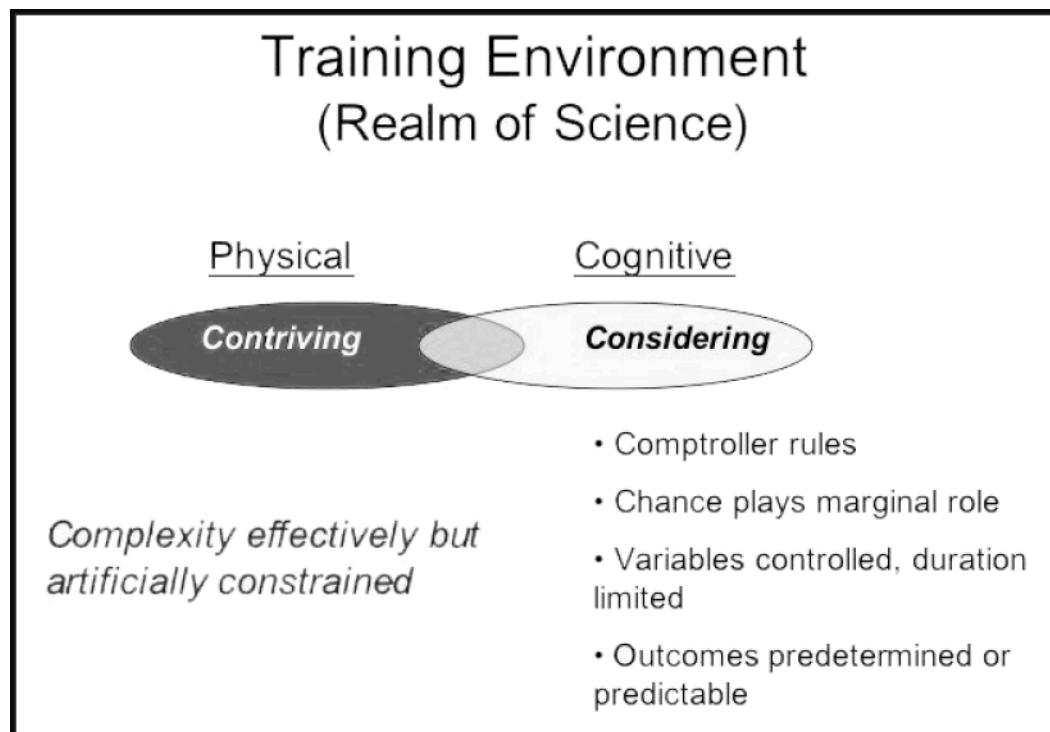
According to Aristotle, art is all about this reconciliation between the cognitive process of considering on the one hand, and the physical process of contriving with or manipulating the materials on the other. Chance is the leaven that somehow causes the imagination to rise to new insights, which in turn affect both the considering and contriving.

Dante's idea is of particular interest; that no art is possible unless this struggle, this "coming into being" takes place under the pressure of some severe constraint. The "Curb" or constraint that Dante labored under was the dual yoke of rhyme and meter. By subjecting himself to the discipline of writing in rhymed couplets, he imbued his "Divine Comedy" with a gripping forward momentum that propels the reader onward in anticipation of the resolution of the next metered set. The rhyme and meter set the "context for understanding."



Hegel's view of architecture (which he considered a fine art) has relevance for our concept of the GIG. Just insert the word "Network" in front of this paraphrased quote from his Lectures on The Aesthetic and I think you will see what I'm getting at. Concentration of spirit has to do with supporting the capacity for intuitive reasoning and judgment, while giving "direction to the mind's absolute objects" has to do with implementation of vision. This process of "considering and contriving" within the "leveled space" of a global information grid is the essence of Net-Centric warfare. The COSMOS ACTD is about preparing us to be both architect and artist.

But before we jump into the realm of war, I think a few words about training are in order. Our concept of training, and by extension our understanding of the wartime demands on our networked communications architecture, falls short of the demands of art.



Slide 4

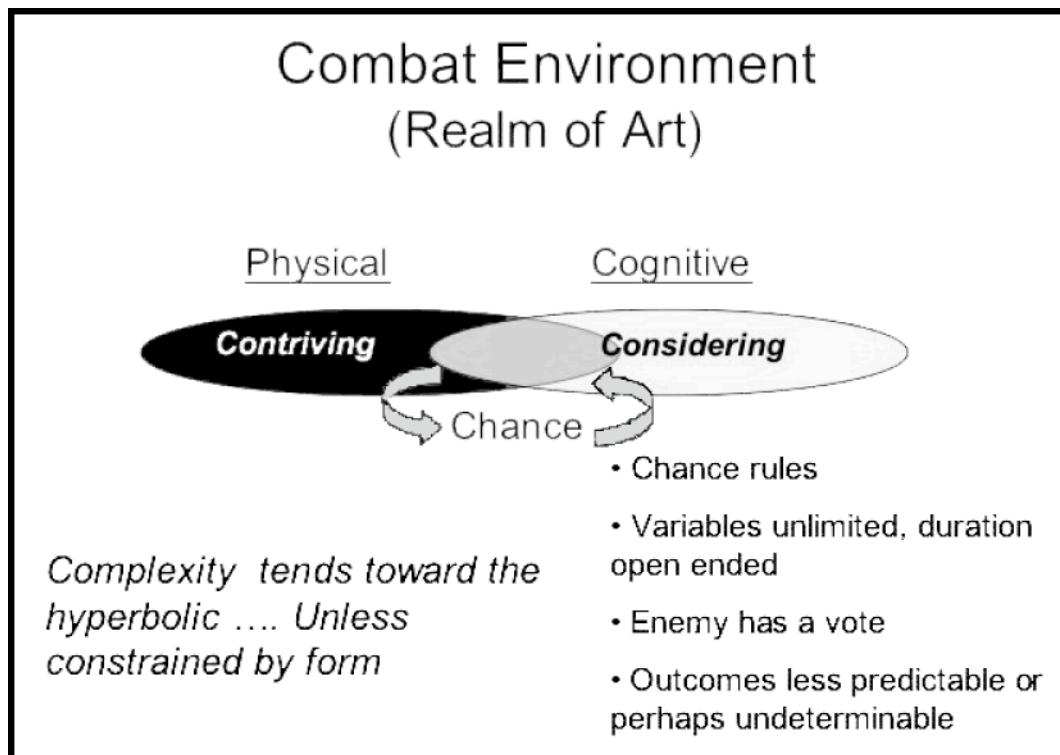
Here's how I see the Training Environment. With Chance effectively marginalized it falls short of the realm of Art. Due to real limitations on time, money, men, and equipment, we have effectively removed chance as a leavening factor.

In one sense this is a good thing, because it allows us to focus our concentration in a few areas or even upon a single variable with a view toward achieving predictable results. Isolating variables and the disruptive intrusions of chance is exactly what we do when we apply the Scientific Method (another contribution of Aristotle's) to learn something about the nature of things. It is a powerful human tool that relies on the interplay between the "Considering" and the "Contriving," to enable us to walk the cause and effect chain backwards and thereby dissect in a limited way the empirical world we inhabit. It works best in the laboratory.



The problem with training that takes place within the Realm of Science is that we learn nothing of Complexity, a potentially lethal vulnerability in war.

Although heavily influenced by the contributions of science, War lives within the realm of Art, and so must the networks we rely on to maintain our vaunted information advantage. They must be tuned to deal with the lethal threat of complexity, that is to say, they must be designed with a specific purpose in mind, and they must be efficient. Nature abhors inefficiency, and war is Natural Selection on Steroids! Only an efficient network can assure the timely delivery of the right information to the decision maker that needs it.



Slide 5

Clausewitz described war as the "Realm of Chance"! Its influence and direct relationship to the challenge of Complexity were apparent well before the first computer network both enriched and complicated our lives.

Where Chance Rules, variables become unlimited, outcomes less predictable, and as Clausewitz noted, "even the simple things are difficult."

When simple things become difficult you can be assured that it is not just the enemy registering his vote that is the cause.

Complexity if unconstrained moves toward the hyperbolic. I believe that this is a potentially lethal vulnerability in the Net-Centric environment where computer networks are supersensitive

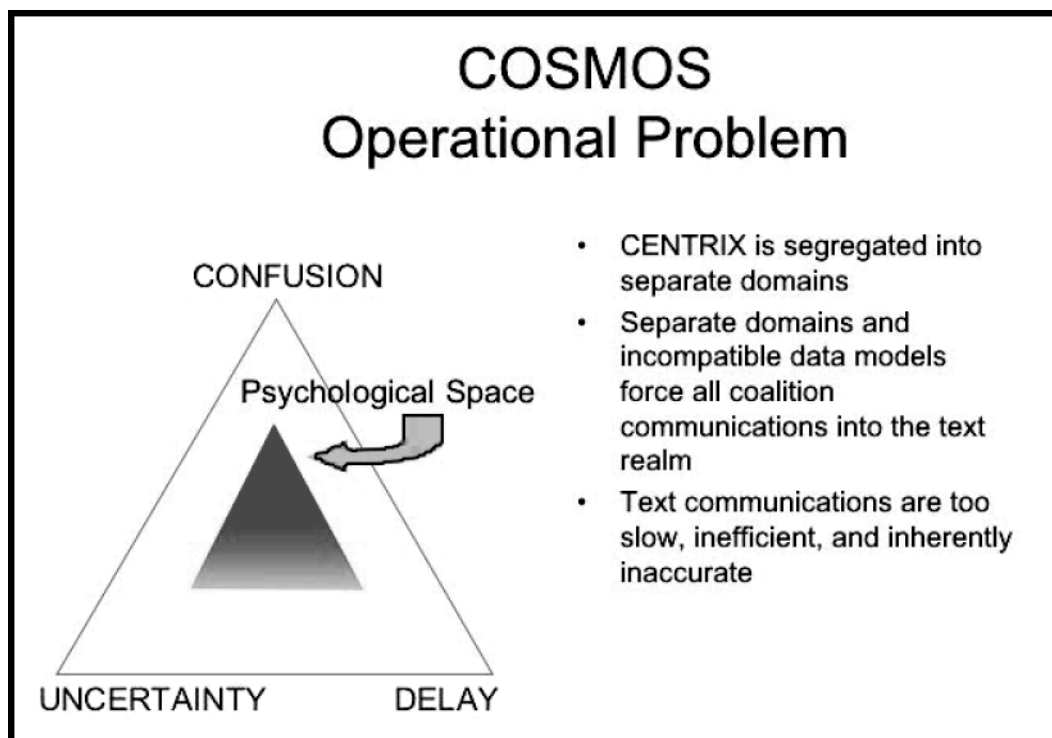


to feedback loops that can turn our information systems into purveyors of ever increasing volumes of irrelevant data.

Commander's drowning in torrents of useless information is symptomatic of a communications architecture that is ill conceived, unbalanced, inefficient, and succumbing to spiraling complexity.

Our only hope of constraining complexity in our C3 architecture is by imposing form suited to its purpose, the way of art. It begins as Hegel observed by "leveling the space," by approaching network design as an art form.

In Operation Iraqi Freedom concerns with releasability of information among allies forced us to segregate coalition partners in separate CENTRIXS domains. It seems that the purpose of the CENTRIXS architecture was to frustrate rather than promote integration. The need for information protection rather than information sharing drove design considerations.



Slide 6

Despite the difficulties encountered in OIF we have made no changes in the CENTRIXS architecture and in fact continue to add separate "stove piped" domains, one for each new coalition partner. Separate CENTRIXS domains are crushingly inefficient on the battlefield. It forces us to field additional equipment and restricts coalition communications to the text realm, where translation burdens add further delay and inaccuracy.



Confusion, Delay and Uncertainty, all manifestations of the phenomenon of complexity, are facts of life on the battlefield. To be rid of them would be ideal. We know from Art that while the Ideal is unachievable, it is not unapproachable. We need a CENTRIXS network architecture that shrinks the Psychological space defined by these three battlefield facts of life. That is to say, we need a network design that constrains complexity, promotes integration over segregation, and a data scheme that permits the direct exchange of information machine-to-machine.

We need a new architectural vision for CENTRIXS, in which the purpose of the network is viewed as the integration of coalition efforts as opposed to the restriction of access to information.

## **COSMOS Requires A Transformational Solution**

- **Because the problem of complexity is growing exponentially leaving our inefficient networks prone to catastrophic failure**
- **Because our potential adversaries are becoming more sophisticated in their abilities to exploit the inefficiencies of our networks.**
- **Because Net-Centric warfare will demand agility and flexibility that our current network architecture cannot provide**

Slide 7

We need to move the Coalition C3 effort from the disconnected “stove piped” reality we experience today to the realm of Art where form supported by the concepts of balance and proportion offer the only hope of constraining complexity.

I believe that a transformational solution to the problem of coalition integration is advisable for what it can tell us about the much larger challenge of designing and managing the GIG. The tools of art applied to the challenge of managing complexity in the coalition arena, are also applicable to the much greater challenge of designing the GIG to function in the realm of war. The concept of Dante’s Curb of Art is really the key to understanding how an artistic solution applied to the more manageable problem of coalition integration on the battlefield can be expanded to address the challenge of integrating COI across a global grid.



## COSMOS Conceptual Solution

- *Use a common data model* to enable the automatic sharing of information (data in context) at the machine level and unleash the potential of smart agent technology
- *Collapse the multiple coalition domains* down to a single integrated network while maintaining cryptographic segregation of allied access to a “Shared Space” where coalition data is accessible
- *Tag information for automatic release* to selected coalition members based on role
- *Demonstrate, through Exemplar applications*, the exchange of “data in context” across service and national boundaries independent of application

Slide 8

“Leveling a space for the concentration of spirit and for its direction to the mind’s absolute objects” was Hegel’s challenge to architects. Our task is to define a virtual space that promotes the integration of coalition efforts in the combat theater.

Collapsing the CENTRIXS’ domains down to a single integrated network does not require that we abandon access controls over classified data. It does require that we establish a purpose for the network, and then let that purpose define the form or architecture. The objective of COSMOS is to integrate coalition communications in such a way as to enable the full potential for data exchange in the Net-Centric environment. This purpose then drives the form, the collapsed network with access to a shared space where coalition data is accessible. The form enables or, to paraphrase Frank Lloyd Wright, “follows function.” The form, if balanced and suited to its purpose, also gives us an approach to constraining complexity.

The greater challenge in applying the principles of art to coalition integration is to select Dante’s Curb! What yoke or constraint can we shoulder in order to release the creative advantage of intuitive thinking, and bend our collective wills relentlessly toward the dictates of efficiency?

My answer is that the data model can serve the same purpose of rhyme and meter in poetry and provide the “context for understanding,” the essential precondition for all efficient communications. The data model can provide the “context for understanding” that enables the sharing of information across boundaries, independent of application. The data model can help



generate a forward momentum in our communications that anticipates need and pushes critical information to the individual that needs it.

The COSMOS ACTD will demonstrate the potential of purposeful form in network design, and a common data model to effectively integrate coalition communications.

## COSMOS Technical Approach

- Employ VPN technology and if available CBIS encryption to maintain cryptographic separation among allies accessing the shared space
- Demonstrate the usefulness of a common data model(s) for exchange of "data in context" across boundaries. Since Command and Control cuts across all COI(s), begin with the C2 data model adopted by NATO and endorsed by DISA for NCES interaction, C2IEDM
- Bridge Exemplar Applications to the common data model using Open Standard Software Development methodologies
- Leverage Smart Agent and Portal technology to meet user defined info requirements

### Slide 9

The technology is not the biggest challenge in implementing the COSMOS vision. There are several encryption technologies we can explore, either separately or in combination, to safeguard information in the shared space. The challenge of bridging legacy applications to the C2IEDM model is also manageable. And the use of intelligent agent and portal technology to find and display vital information on the screens of key decision makers is practical once the "leveled space" has been established.

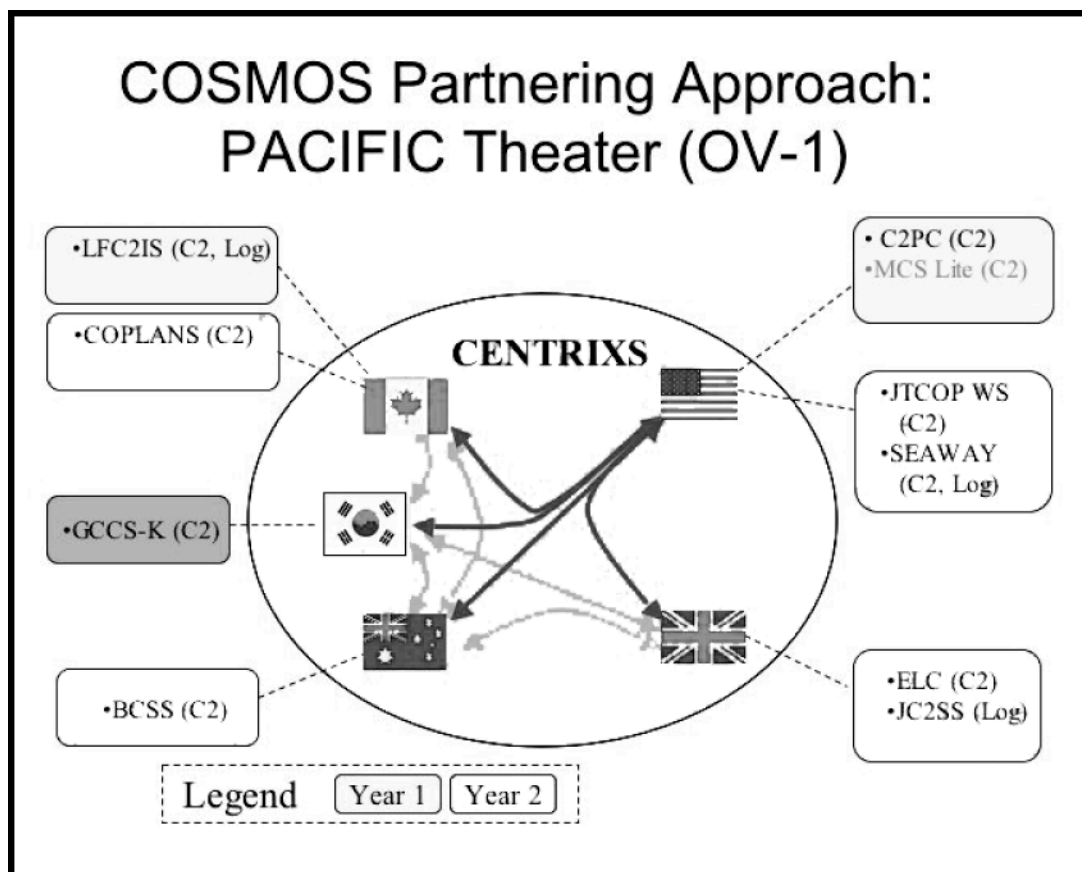
The greater challenges to realizing the potential of Net-Centric operations are not technical but cultural. We must overcome our tendency to approach new network design from the perspective of the perceived shortcomings of our current systems. For example: more bandwidth is not the essential challenge in designing the GIG, but certainly its inefficient use is a problem we want to avoid. The challenge in designing the GIG is defining its purpose, and aligning the Communities of Interest (COI) whose participation is essential to its successful implementation.

I believe that the greatest risk in undertaking a project of the size and scope of the GIG is our old adversary "Complexity." The larger the networked architecture, the more opportunity for inefficiency to gain an upper hand and drive complexity to destructive levels, especially in time



of war. Our only chance of managing the threat of complexity is through “form imbued with purpose,” which by the way is Immanuel Kant’s definition of Art.

I will not presume to propose a form for the GIG. On the one hand, I’m not smart enough, and I don’t have a clear enough understanding of its intended purpose on the other. But I know that I am on safe ground when I say that the COSMOS ACTD will generate insights into Net-Centric reality on a small scale. And that some of these insights will be of great value in the overall design and implementation of the GIG. And I suspect that the “Curb of Art” that we propose for the COSMOS ACTD to provide the “context for understanding” that enables the exchange of data across boundaries, will serve the same purpose equally well for the GIG.



Slide 10

Here’s a conceptual view of the collapsed CENTRIXS network that will provide the “leveled space” for the exchange of information or “data in context” across boundaries and independent of application.

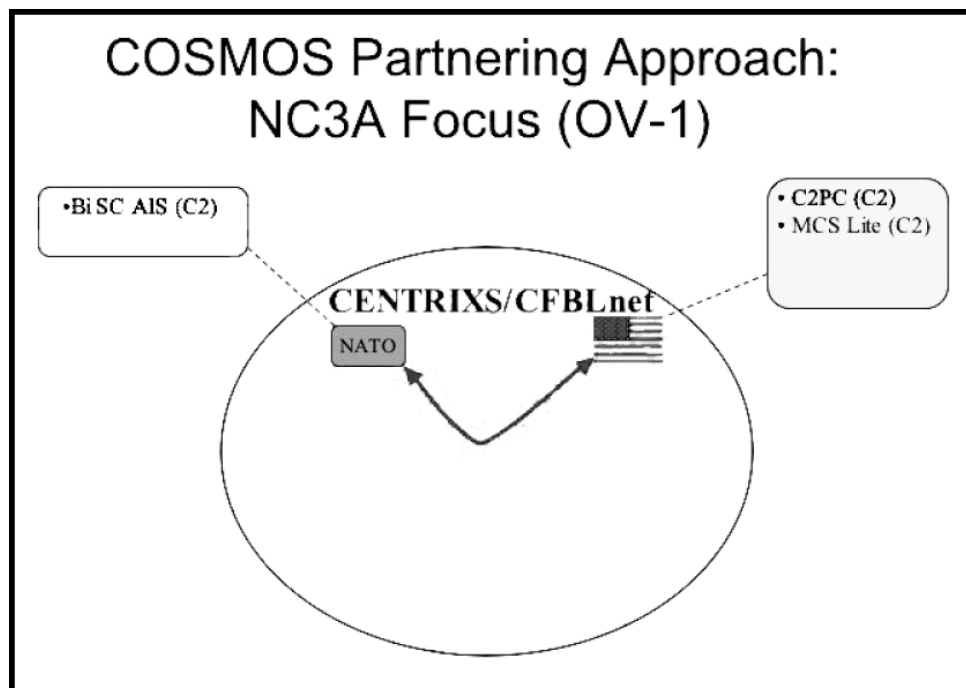
The applications depicted are COSMOS exemplars bridged to the C2IEDM model. We have borrowed the term exemplar directly from philosophy where it refers to individuals or systems that embody those traits or virtues one hopes to spread throughout the larger society. We want to demo exchange of “data in context” or information machine-to-machine among different service



and national applications. And we expect to gain important insight into Net-Centric reality in the process

The FORM of the collapsed network, and the advantages in efficiencies it offers over the current stove-piped arrangement of CENTRIXS domains, is obvious. What is not so obvious, but is perhaps of greater importance, is the empowerment that compliance with Dante's Curb of Art offers. It is of course the shouldering of the Curb or constraint of the data model that enables the exchange of "data in context" and it is the virtues associated with the efficient exchange of this information that we want to inculcate in the larger society of the GIG. These virtues include:

- \* The ability to discretely tag data as releasable to different members of a coalition based on role or some other criteria.
- \* The ability of intelligent agents to glean critical data elements from diverse sources and display them in the manner most useful to decision makers.
- \* The ability to shift much of our communication from the text realm to machine-to-machine, thus eliminating much of the human handling and translation requirements.
- \* The ability to support intuitive reasoning by enabling commander's to adjust the quantity, variety, and content of information that competes for their attention.



Slide 11

The NATO C3 Agency employs the C2IEDM as the data model for exchanging C2 data among the 20 allied nations of the alliance.



## Partnering Agencies and Allies

- OSD NII
- DISA NCES & GE2
- DUSD AS&C
- USMC
- USA
- Australia
- Canada
- UK (tentative)
- NATO C3 agency

### Slide 12

These are the nations, services, and agencies that have signed up to support COSMOS. We are recruiting COI that have a crucial interest in exchanging data across boundaries. We think that the COSMOS experience will help them get organized and give them a head start in determining what data under their control should be shared across the network.

The process of identifying COI and encouraging these self-organizing entities to commit their data to be shared across the GIG has been identified by the GAO as one of the fundamental challenges to implementation of the DOD's GIG vision. The sharing of data by COI does not mean the adoption of a common data standard, but rather the mapping of data elements to be shared to the common data model.

I believe that the COSMOS ACTD can play an important role in providing COI with a glimpse into the Net-Centric future and thereby assist them in preparing for it.



Expected Benefits	
First Order	Resolves operational problems
	✓ Reduction of complexity and equipment duplication
	✓ Support machine-to-machine exchange of vital info
	✓ Reduction of text traffic and translation burden
Second Order	Doctrinal Solution for implementing DoD's Net Centric Data Strategy
	✓ Pathfinder for the DOD Net Centric Data Strategy
	✓ Extensions to the data model in support of COI's
	✓ Assessment of CDR's Info needs as a GIG design criterion
Third Order	Transformation
	✓ Insight into NetCentric information flow
	✓ Insight into the optimal form of the GIG
	✓ Insight into how to "Fight the GIG"

### Slide 13

The expected benefits of COSMOS are intellectual products rather than hardware or software products. The first order of magnitude benefits address the operational problems with coalition communications experienced in OIF. But the “form imbued with purpose,” and the “Curb of Art” used to realize these first order benefits have implications that extend well beyond the combat theater. Addressing the challenges of coalition integration at the operational level of war with the tools of art offers insights and possible solutions to the much larger and more complex strategic challenges we face in implementing the DOD vision for the GIG. The second and third order benefits of COSMOS will provide valuable insights that might save time and money in this \$21B effort.

The July 2004 GAO report entitled “The Global Information Grid and Challenges Facing its Implementation” lists several concerns to include:

- \* The challenge of implementing a project of this magnitude.
- \* The inherent risks of protecting data within the thousands of systems to be integrated into the network.
- \* The challenges of sharing information across business and war-fighting operations.
- \* The implications of sharing time sensitive data in NetCentric operations.
- \* The identification of COI and the processes for their collaboration in the sharing of data.
- \* The implementation of a DOD Net-Centric data strategy.



- \* The requirement for a roadmap for DOD components to follow in migrating their systems to the GIG.

In conclusion the GAO noted, “ While DOD’s vision of the GIG is compelling, the breadth and depth of the GIG and DOD’s objectives for net-centric warfare, present enormous challenges and risks – many of which have not been overcome in smaller scale efforts, and many of which require significant changes in DOD culture.”

The COSMOS ACTD is a small-scale effort that proposes to employ the most powerful tools the rational mind has yet to devise for tackling complex problems, the tools of art. I think its an investment worth making.









**LCol. Jacques Hamel**  
The Canadian Forces  
Project Manager, ISTAR

Good morning ladies and gentlemen. Twenty-one years ago, I was walking into Courthouse Bay in Camp Le Jeune to learn about some of my trade as an engineer officer. Today, I'm visiting the Marine Corps Base at Quantico to talk about what we're doing in Canada as a partner in this interoperability issue with the U.S. Many of our lessons are the same as yours we're moving down the same road with the same pain.





My Community of Interest as Project Manager of ISTAR are the warfighters, from the soldiers to the naval task groups. I started as an integrator for the land warfighter that brings in the joint and multinational picture. This is not a simple problem, because all of those communities out there, the legacy that they're pulling behind them, makes your cost go up and makes your complexity go up. We have to find a way to bring that down and one of those elements was discussed earlier by Dr. Pohl.

We all have the same information needs on the battlefield, be you Army, Marines, Navy, or Air Force. You all have the requirements to know where we are, know what the force is of our enemies or belligerence. We need to understand the environment and the conditions of the environment. We need to understand the situation. But, most importantly we need to understand the context in which it's presented, be it overlays, fusion, or another element, you need to understand this context. Without the context, the linkages are missing.

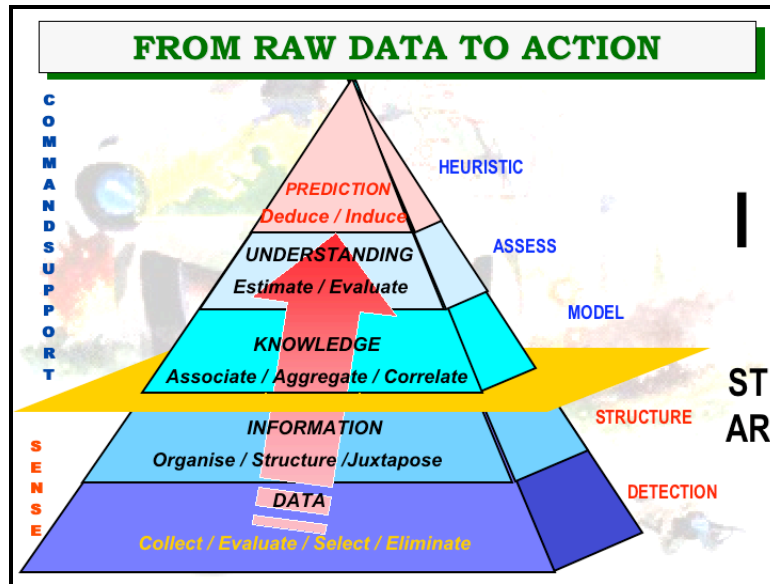
The slide features a Canadian crest in the top left corner. The title "Battlefield Information Needs" is in large blue font, with the "ISTAR" logo in green and yellow to its right. A bulleted list on the left details information requirements. On the right, a composite image shows a soldier's helmet with a digital display overlaying a battlefield scene with soldiers and a helicopter.

**Battlefield Information Needs** ISTAR

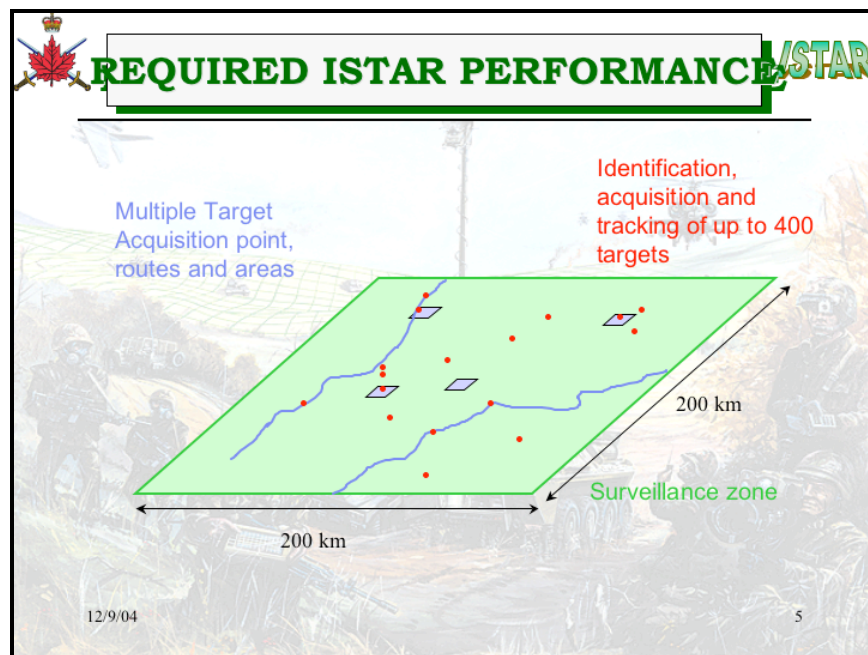
- Friendly or Enemy Forces
  - Force Composition, Disposition, Sustainment
  - Mobility and Transportation
  - Weapon Systems and C4I
- Environmental Conditions
  - Physical (Land, Sea, Air, Space)
  - Civil (Political, Cultural, Economic)
- Situation Awareness
  - Mission, Intelligence, Targeting
- Operational Context

Currently, when you're driving up the information chain, most of what we've been able to do, dealing with automation, maintaining the information layer, dealing with knowledge, understanding and the ability to predict, is still in the realm of the human today, because we haven't been very good at quantifying where we're going and the people we are fighting don't seem to want to be predictable anymore.





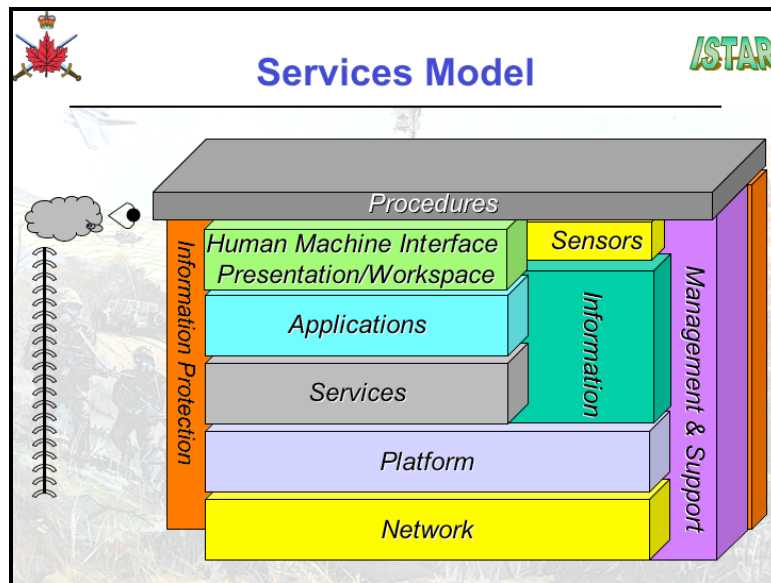
Our area of operations has also changed dramatically. What used to be core area of operations now can be the responsibility of a brigade, or in some case in lower level operations of a battle group. So, there is the need for surveillance in the areas of 200 kilometers or more, with the ability to target within areas, specific areas or managed routes, and be able to track those target's, to be able to either maintain that knowledge about them, or to be able to prosecute them. This is a tall order if you were to do it the old way.



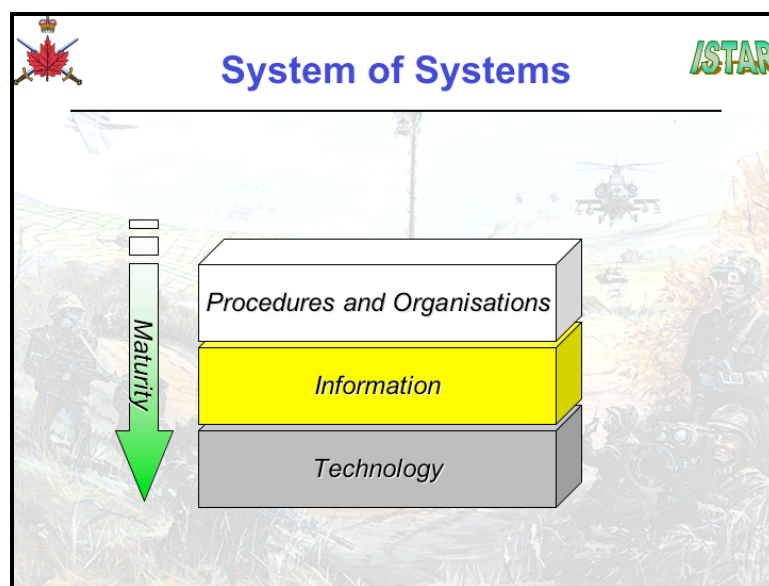
In order to get there we have to adopt a service model. The simplification of it, our backbone is our network. No different than your GIG architecture, but what's important in there is there are three services within that model that will repeat themselves throughout. The information that we're sharing, the management and support of the environment, and the security. We didn't talk



about security earlier today, but this is the toughest problem to crack in order to maintain joint multi-national and interagency capabilities, especially when you're dealing with different security levels.

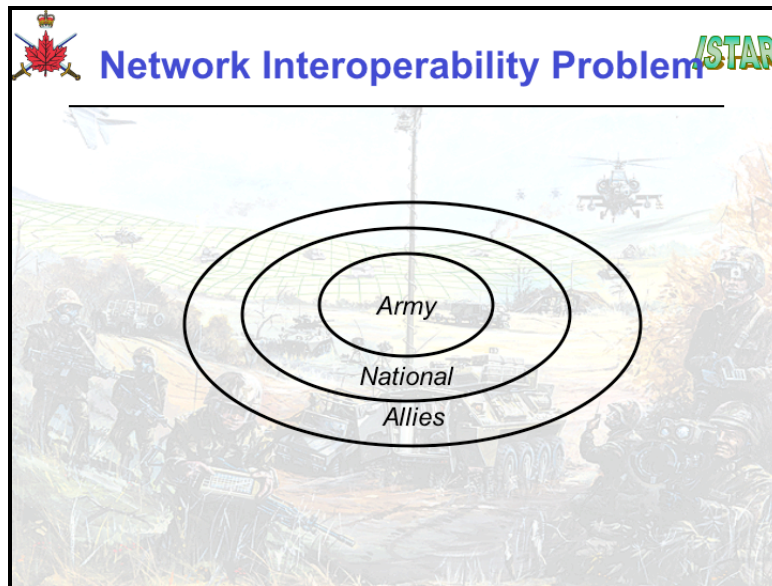


You have to have sensors coming into your service architecture and finally, we need to put the brain bucket in there. Again, there's one thing that transcends everything and this is where the human comes in. All of this automation is only possible if we have common procedures or repeatable procedures of some sort. So, we can either impart them to the machine or we can get people to understand what they're using. To drive it from the network up. You're going to end up with this joint procedure at the top. You have to get it down the other way around, meaning the warfighter is involved from the beginning. This is not a simple process, because we tend to get nervous when we hear the word "network".

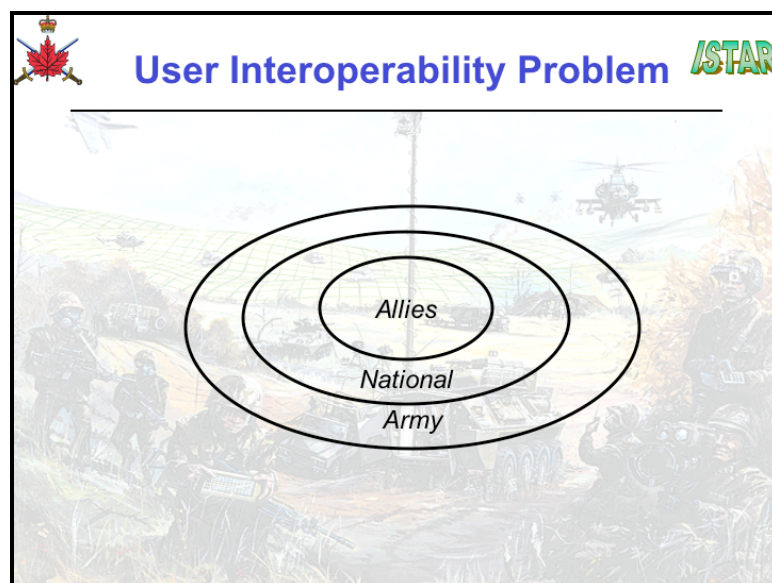




Today in Canada, like in the U.S., we seem to have cracked the technology side. Technology is now something we can manage. We can move forward on it. We're slowly integrating at the information level. It's going to take a while longer, but our procedures and organizations that are supporting the warfighters aren't what's dragging us back. It's going to be a couple more years. We need to work with it to get forward and to actually get the advantage that we're looking for.

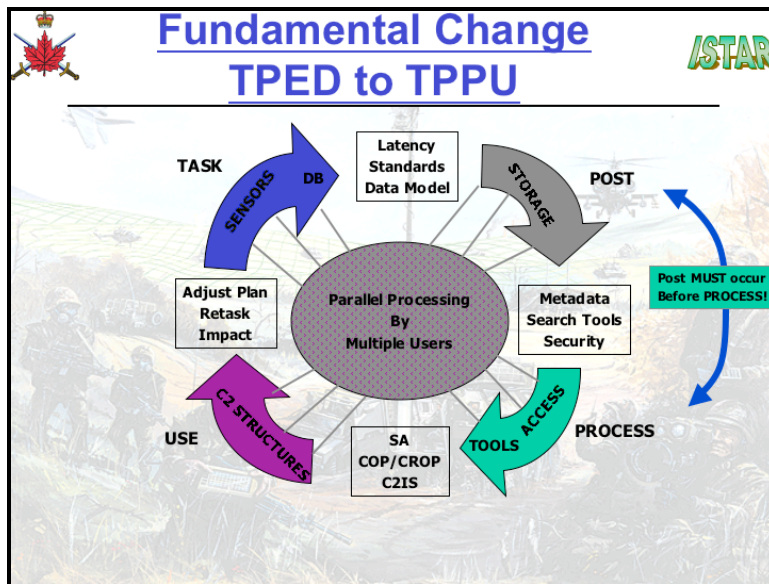


Classically, when we look at interoperability, we've been looking at the network interoperability as driving the command and control of the information probability. And, classically, it's easier if you're doing it from yourself, be it the Army or Marine Corps or the Navy than looking at your national joint level, and then looking at your allies, because the complexity grows as you go out. Both from the networking and a security perspective. What we found in our own work nationally, it's not true when you're dealing with the information itself or the applications.





We found through our work that started by looking at papers written in this country in the mid 90s that was easier if you start with your allies, because at the information and functional level is what we have the least in common. We have a small amount in common. The processes are fairly simple because our doctrine are all a little bit different, and therefore if you start with your allies and you grow to deal with your joint problem and then your single service problem at the end, life is easier. So starting in the mid 90s, Canada put in an investment into looking at the future from an interoperability perspective. This became the primary interface point that we did from a command and control information perspective, at the same time as we were looking at other interface points I'll discuss later.

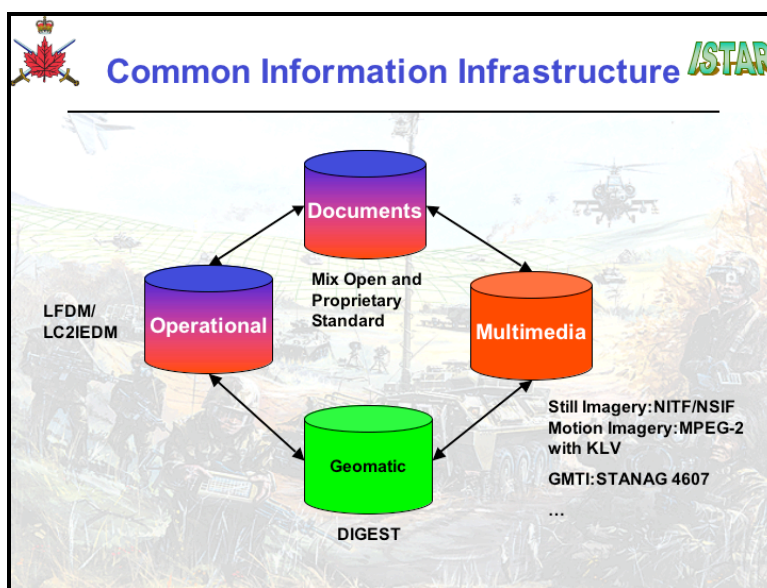
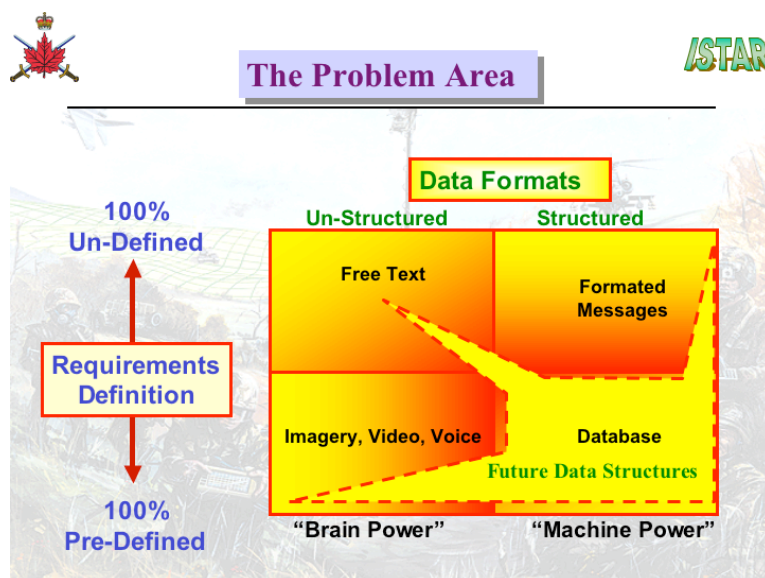


One of the changes that we're looking at right now, that's coming from here conceptually, is the change in how the intelligence process is working. As the PEO responsible for all ISTAR Projects within the Canadian Army, I need to be able to go from the old process to the new process; the concept is there, but I can tell you that people may not understand the process yet, and it's slowly changing, but as we get forward this will fundamentally change how we work below the surface. By going there multinationally, understanding the TPPU process multinationally first before we try to derive our own tactical sensors into it, life becomes easier, and we demonstrated that a couple weeks ago when we engaged in a Canadian exercise that had multinational components.

In our problem area, we have to deal with most of the information coming from an unstructured be it free text, imagery, video, voice to very structured information. We made a conscious decision to concentrate on structured information, however, in order to prevent significant data incest. The main thing is contacts and linkage back into your unstructured information, so you're able to, once you've done the analysis image, or you've extracted the concept from the text, know that what you've created as information for the warfighter came from that source. So you don't lose the context. Otherwise you may be at risk of reprocessing the same image twice, or reprocessing the same information twice. So, from our perspective, we're looking at four large databases or data sources. They're not specifically RDBMS or otherwise, but we're



dealing with operational data as one Community of Interest from a C2 domain. We're dealing with Geomatic data, they were there before most of us; the NEMA community started very, very early at structuring the information. We're dealing with multimedia information, be it imagery, GMTI or voice, and we have the quintessential problem of documents. None of us have high standards and right now this is one of the areas where we need to get better at. Otherwise, they become the boat anchor. So those are the four forms of information we're dealing with, and trying to assemble the ISR architecture in Canada.




So, what's the data model? My simple way of the world, there's an academic way of looking at it, but as a warfighter I have to look at it in terms that are easily explained to the people using it. It's their dictionary and their grammar. In this case, what we have to look at is find the form of Esperanto where the human can talk to the machine, and the machine would understand it. When two machines would talk to one another and they would understand one another. If you



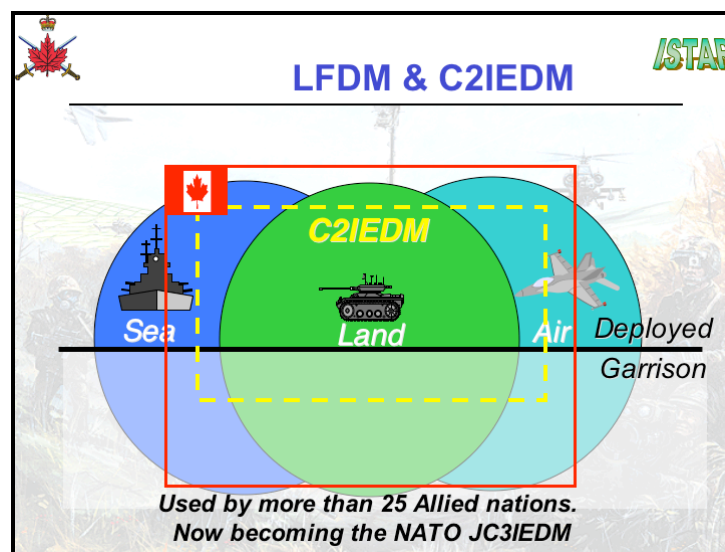
talk to the next human in its own language they will still understand the intent and the context. This is critical. We can do that today with Geomatic information and command control information based on the C2IEDM. We're slowly getting there, to do the same thing on multimedia information. It's very hard with documents.

### Why a Data Model?



- A specification of the data structures and business rules needed to represent and support a business area.
- It is the dictionary and grammar used by humans and systems to communicate.

So what we did is we started with the core, the C2IEDM, and built around it natural extensions. You don't have to be stuck to only using the international domain. As long as you respect some rules in building your own model, you can extend it to deal with security issues, issues of purely national means, and from there build the ontology to the point where you can use it. Our initial need, interestingly, was not warfighting. It was in the mid 90s' fiscal crisis. We had to figure out where we were spending money on what, so there was a fair amount of extensions done to deal with financial management, and performance management, for the Army. So that was where it started, and it also went into the warfighting around where were truer to the international domain with some extensions.





So what we looked at for extensions for ORBAT management and how we task organized. Intelligence and EW, subjects that don't get shared easily internationally or in large international communities. Operational Planning because we all do it a little bit differently. Security Labeling, be able to deal with guarding of information. Materiel Management for the logisticians. Human Resource management, because internationally all we care about is the number of soldiers you've got; you don't need to know all the details to manage their health, or the information about them. In our case, Financial Management was another extension we did.



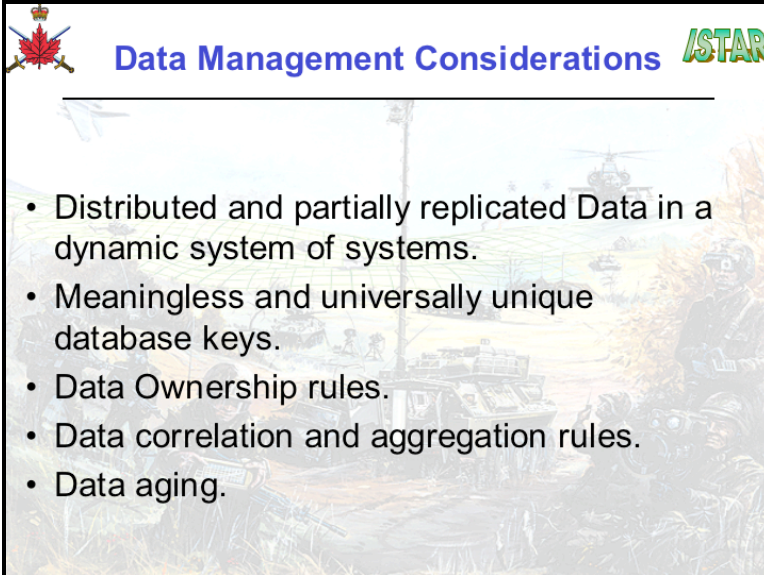
Building a data model alone is not enough. This only walks you through a small amount of the capability. The next element you have to look at is the dynamic nature of the warfare, and look at how you will partially replicate the data around the battlefield in order to serve each commander. If you replicate everything everywhere, you'll never have enough bandwidth. If you don't replicate enough, they won't have the common relevant picture of their level. So it's important to understand the dynamic and have this process that's managed based on the commander's CCIR and therefore it's based on ownership management, rules and filters

If you have a data model and you have no means of having a unique addressing scheme the same as the internet using IPV4 address to make sure we all have a different address on the network, and we're running out of addresses, you have to do the same thing with your data element. A data element, information element, has to be uniquely identified worldwide and inside your Community of Interest, otherwise two of you will use the same postal address or the equivalent, and you'll end up with significant system crash. This is the legacy of the messaging environment where you could reprocess the same message and get information twice. This is something that must be managed in the environment

Next is data ownership rules and respecting it, and the implications for both security and operational use of that data. To create data on a data element that belongs to one of your allies or belongs to somebody else inside your organization. You're not overwriting what they have you are amplifying because if you overwrite you're erasing the past and erasing the past is not a



good thing, especially when you're trying to deal with your warfighting systems where lives of people are at stake.



### Data Management Considerations

- Distributed and partially replicated Data in a dynamic system of systems.
- Meaningless and universally unique database keys.
- Data Ownership rules.
- Data correlation and aggregation rules.
- Data aging.

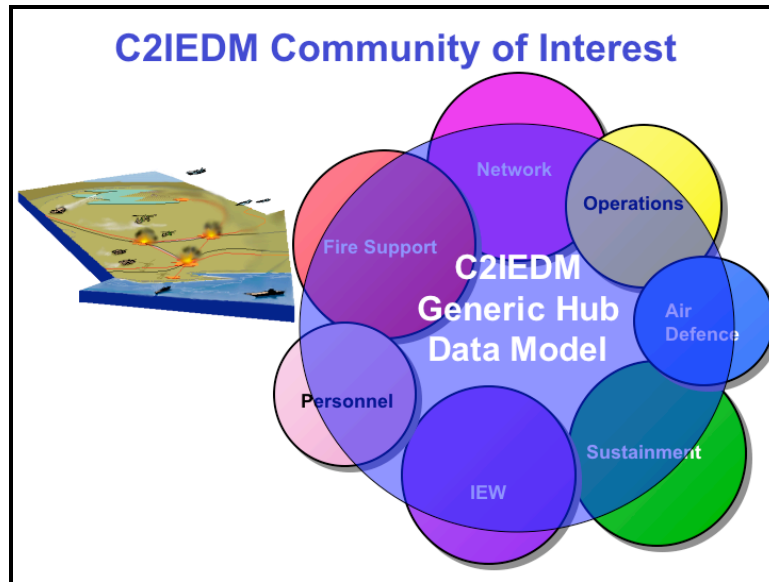
The next one is not trivial. How do you aggregate and how do you correlate data elements? Two of us sent a spot report on the same tank on the hill at two different times. How do you get that correlation done? What are the rules you want to use there, and how do you present aggregated positions, aggregated holdings, aggregated capabilities? How do you present that? What are the rules you want to use in this area? This is the tougher part where the warfighters have to define how they want to present those; is it pure mathematical sums based on algorithm or is it something a little bit better than that? Because right now if you have two companies on one side of the river, one company on the far side of the river, you may end up with a battalion right in the middle of the river, which makes no sense.

The last one but not least, since the data we're dealing with is like for banking, the passage of time makes some of the older data irrelevant to your current fight, you have to deal with data aging and presenting that to the users, so your user community can represent what is current data, what is older data, and what is data that should not be taken into account anymore. Data aging is another significant factor that must be taken into account.

So earlier today we talked about Community of Interest. We identified one of them. There's one out there called the C2IEDM community, MIP community where it was a landcentric warfare community that looked at command and control. That Community of Interest was made up of a series of smaller communities of interest that looked at IEW sustainment, air defense networks, fire support, personnel. When we all started we thought we were all very different. I'm a combat engineer and I thought I was very different and my way of command and control was very different than the infantry, was very different than the artillery. We got very surprised. We have over 90% commonality in between the different communities once you start really digging back down and forcing people back to the logic in what they're saying, out of their legacy into the common logic. Once you find that you have to have 90% commonality, you call that common command and control. You let the special extensions to deal with fire support



computation, air and joint warfare signals analysis, in that community. You don't try to impose that on everybody. But, there's a large amount of commonality that was identified in doing the work on the C2IEDM. So we went from seven or eight BFAs or separate systems in Canada. We're collapsing to a single one right now for land warfare over the next two years.



For me, under ISTAR, which is bridging the C2 and ISR communities, I need to bridge other communities of interest. I need to be able to bring in the command and control community, which is one Community of Interest which is important to me. There's a second Community of Interest which is emerging, called CAESAR/MAJIIC, CAESAR old name, MAJIIC new name. It's sensor information. Eleven nations in NATO, seven up to this year, were dealing with EOIR, SAR and other sensory platforms to bring them together to a common standard similar to what the MIP C2IEDM did, but at the data level. This is a second Community of Interest, which is critical, the naval and air community have had the Link Community of Interest for years, and it is a Community of Interest that has to be reckoned with, because it has specific characteristics tied to real-time operations, that must be integrated properly.

Again, you have the Community of Interest which at its surface is not information based, but is based on common principles, the CANUS or 4EYES security or compartmented information, is issues we have to deal with if you want to be able to warfight, together, with your allies and the safeguarding information of your allies. The DGIWG which is the NEMA based geographic information community, is another Community of Interest. Those are standing communities of interest that do have rules or data models today. The data model for DGIWG is digest, the data model for the MIP is C2IEDM, CAESAR/MAJIIC has a series of information models that are at the object level, dealing with multimedia capability, the Link Community of Interest has a data dictionary, and the other part, like I said earlier, is based on rules at the moment. We need to expand that either into the ability to guard for reuseability or for the ability to mark information up with details that are not sharable with your other allies.





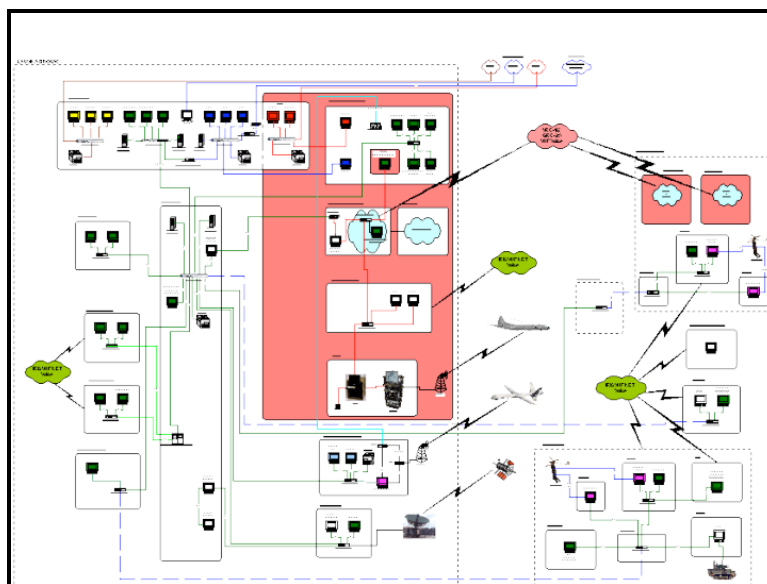
This is all well and good. As a project manager, I can't go anywhere unless I demonstrate some capabilities to get the people that have money to give it to me to go to the next step. So the last month we conducted an exercise called ALIX, Atlantic Littoral Exercise, and it was happening anywhere from Halifax all the way to Batton Island. It was a joint exercise with the interagency component in it, and some multinational components. In there I tried to weave most of those trends we talked about earlier, in the different communities of interest, looking at the areas where we had commonalities and where we needed translators, and we tried out some of those translators.



So we built an operational architecture that provided me the ability to have a command and control environment as part of ALIX was operating at the unclassified level to be able to deal with information with other government departments on shipping, was operating at the secret level, RELCAN to deal with NORAD information on recognized air picture and be able to deal



with task force at seas, and I had some specialized equipment deployed there to deal with IEW. So the red part is what we were running purely at the secret, RELCAN (releasable to Canada) or CAN/US eyes only, the rest of the environment was operating at the releasable to For Official Use Only, within Canadian government. Next year when we run the same experiment, we're going to run most of it at the secret level with some above secret, and we're going to keep a small enclave at the unclassified level. What we did, we provided C2 tools, battle management tools, planning tools that were enabling people to deal with electronic up orders, collection management tools to deal with the RFI process, document management, to be able to deal with the linking and producing documents, knowledge database about our lessons learned, imagery visualizations, primarily one of your products like the JIVE and ITS, so those were the tools that we have in the inventory today that are with our warfighters for doing their job. We added some tools, automation coalition tools for free text were added, based on commercial technology, expanded to support a translator to C2IEDM. Imagery exploitation the same way, for both SAR, EO and GNTI again translating into reports in C2IEDM. One of the biggest tasks we had after that was to deal with link analysis. Both for human and ESN purposes we were using a commercial tool called I2 and a gut tool from the US called Medina, to be able to deal with ESN and be able to provide in C2IEDM, format networks, nodes, location and network analysis to be able to link us back to other people. And, keep the analytical side for the all source cell environment.

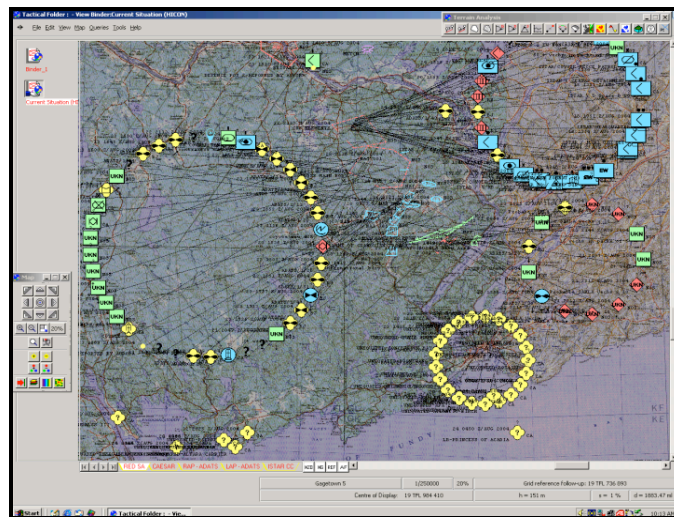


In order to meet my joint requirement, I needed to be able to start the exercise with a recognized belligerent picture, so we built and tested a MIDB to C2IEDM translator, and if you think it's fun, no it's not. It's doable, but it requires a lot of subject matter expertise to do it, because the language of the two is two forms of English that don't exactly match in the middle. We then wanted to bring in the recognized maritime picture and recognized air pictures, and to do that we did a bidirectional interface with TDBMS on DXM. We had a NORAD feed coming in and that link 11B coming in, again with a translator going into C2IEDM. I'll show you pictures of some of those. In order to show the nature of the operation I was into, we also wanted the local air picture so off of a real surveillance radar it was feeding it both the real-time on the radar pictures at the headquarters, and another real-time for command and control planning into our C2IEDM

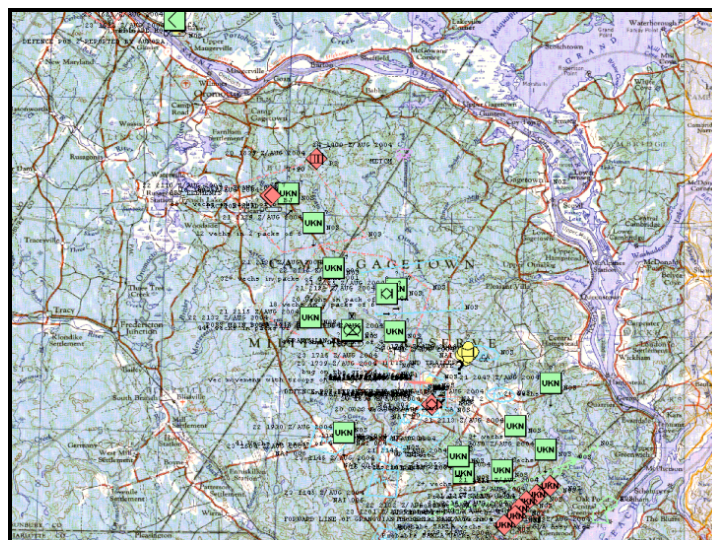


environment. We then wanted to show we could engage, so I had a couple different types of shooters, the one that was the biggest integration we did, our equivalent of your AFATDS called IFCCS where we integrated the fire support environment in order to be able to do air missions and ground missions.

The only part of security we solved was going from low to high, so the agency would be happy with the way we did it. Guarding coming back down is still a traumatic event, and we don't know how to do it yet.

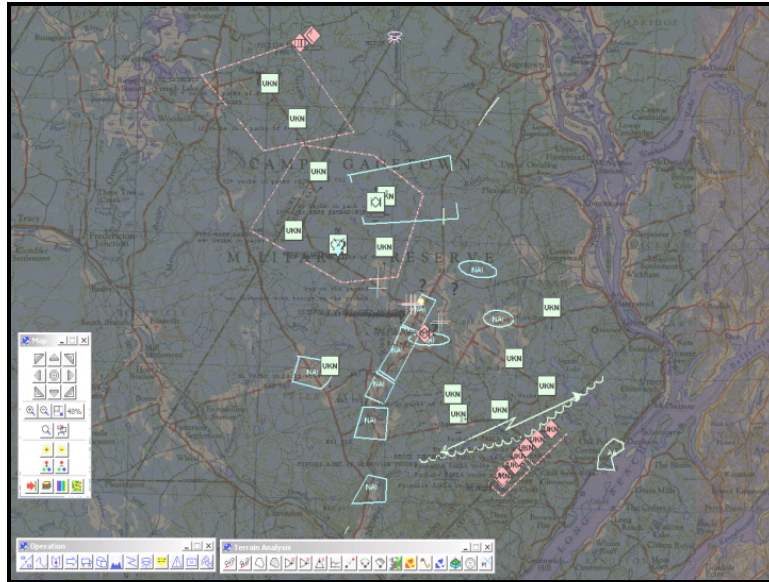


So, to show some of what we did, we brought in both the land pictures, the recognized local air pictures, the unknown that came up GMTI and what was coming off the Coast Guard and like a recognized maritime picture, those were at the unclassified level. What's different than most of the other applications is the context was preserved. By being able to have each one of those sources create their own overlays, you knew what came from where and were able to track the history of the information like you have today, to be able to manage linkages in between them, this is the same as that, or this unit is part of that network, so this was one part of it.

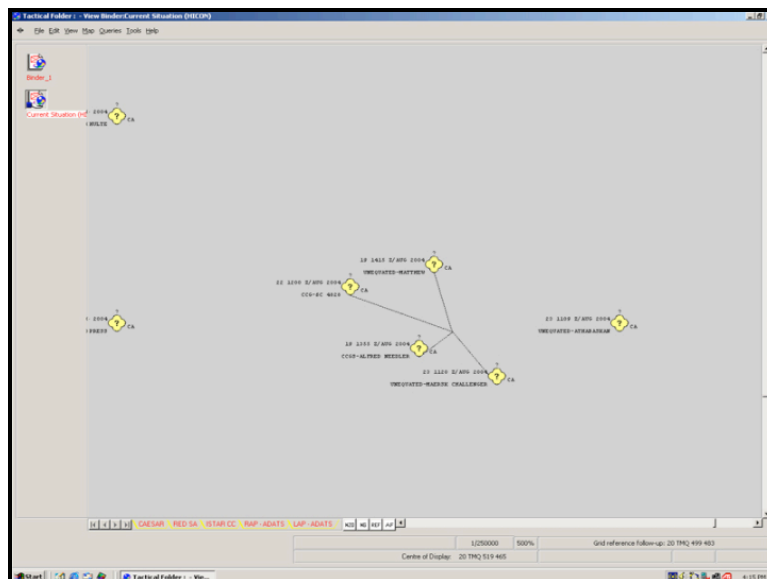




We then were able to come in and integrate some of my recon elements at the land level and have those hits from a recon element, a basic reconnaissance patrol, go back up for targeting purposes to the operational level of headquarters that was in Halifax. In Halifax they were receiving it on GIG Sam, it was starting in the coyote reconnaissance vehicle equivalent to a striker, and being translated seamlessly all the way to us in seconds, not hours.



And then we dealt with the intelligence picture by being able to create the intelligence collection plan, NEIs, TEIs, the intelligence taskings, PIRs and IRs, and be able to get the report directly from the shooters, or the sensors be able to do it, we had direct linkage between vehicles, or fire direction center and the reconnaissance patrols, and we were, doing live engagements on the ground.





We went to the S1 of the task group at sea. I brought the unclassified side of it. We had to strip a fair amount of it, we had a Canadian frigate in the middle of Grand Banks, off link 11B. They sent us back their recognized maritime pictures within 100 kilometers of where they were, and we were able to move that back and forth. On a different demo, in a different setting, we can show the live feed coming in off both an Aurora, like which is a P3 Orion, feeding their recognized maritime pictures and recognized air pictures off link 11B and the same thing off of the DDH. So those things are possible. But at one point there's still some translation issues that we have to get "right-er". So we need to get the subject matter experts together. In our case the next step is: sit a naval officer beside an army officer so they can get the right language. There's a couple interesting examples. It was the first time we were using the P3 Orion in land support with a land warfare group on the ground. So, we tried a couple of things. The first mission they flew, the Orion thought he was talking to a frigate, and the FAC on the ground thought you were talking to an F18. So from the perspective of language and what they had to do, the aviators had a problem with the artillery men on the ground, oh how they would pass targets and just in talking. After the first mission, with the help of a young air navigator who was one of our deployment in Afghanistan, they get the language down right, they wargamed it, and the next day they were doing direct targeting off the Orion, of moving targets on the ground.

One of the interesting attempts we did brought together a commercial predator and the Orion and we put them in a head-to-head competition on who would pass the target fastest back into the fire direction center. The result of hockey game is: Orion 3, Altair 0. And it's not the technology that's that different, you know. The current Orion didn't even have a TI camera, on board, so, the difference was the decision similar to what the Marine Corps did in Iraq. We put a couple ground liaison officers on board. When they got the task to look for a gun battery, they found a gun battery. On the other side, the commercial people operating the predator didn't know what a gun battery was, and so they found me a nice SUV in the middle of a road. So, somewhere in there there's something important that must not be missed. We in uniform have to be part of that process; industry alone can't make it.

That's coming to the end of what I have to say, I'm open to questions and open for sidebar discussion also.



## **Information And Global Integration\***

**Col. Robert C. Morris, US Army  
Chief, Space And Decision Superiority Department  
Joint Forces Command**

### **1. Purpose**

This paper describes the concept of Information Operations that supports the Joint Operations Concepts (JOpsC), the JOpsC Functional Concepts, the JOpsC Enabling Concepts, and related coalition and NATO concepts within the framework of the future Joint Operational Environment. This effort by USJFCOM J-9 will support and facilitate the development and production of USSTRATCOM's Overarching Information Operations (IO) Concept.

USJFCOM delivers not only the IO inputs to the JOpsC, but also a summation of those inputs creating a supporting joint IO concept which is referred to as the "Supporting IO Concept" in this document. As USSTRATCOM develops the overarching IO concept and architecture, USJFCOM J-9 will coordinate and integrate its Supporting Joint IO Concept with them. This will lead to determining capabilities and requirements to execute all facets of IO in future operations. It will both support and build from the Department of Defense Roadmap for Information Operations and other relevant sources. It will apply the principles and capabilities of the joint concept for information operations to the joint operating, integrating and functional concepts.

### **2. Background**

Historically, service and coalition concepts evolved independently, focused primarily on internal service requirements with limited attention given to true joint and coalition approaches. In an effort to mitigate this problem, the Secretary of Defense directed Joint Forces Command to develop the JOpsCs and related enabling concepts. In the area of Information Operations, the Secretary of Defense published an IO Roadmap to coordinate the process for Information Operations in the near term. This intellectual capital must be exploited and improved to achieve full advantage of a vision for warfare that could carry into the 22d century.

Of some 309 transformational issues culled from major DoD organizations in 2003, the Department of Defense and senior leadership reduced the list to 18 issues for experimentation. Information Operations was highlighted as one of the critical areas to address.

In the FY2004-2009 Defense Planning Guidance, the Secretary of Defense designated Information Operations as a core capability equal to land, sea, air and special operations. Further, he designated USSTRATCOM as the proponent for overarching IO concept and architecture for the military.

*\* Paper excerpted from the Information Operations PMP Executive Summary Draft document dated 17 May, 2004.*



### **3. Information Operations – A Critical Need**

Failing to properly develop a future Information Operations concept and integrate it into joint, service, coalition and interagency future concepts may result in slower reaction timelines and situations where Information or other operations counteract and conflict with each other, either neutralizing the desired effect(s) or preventing the force from achieving the desired effect.

Independent or simply coordinated operational plans are no longer acceptable in an environment where potential enemies can rapidly alter battle space, and where a myriad of inter-related social, economic, military, civil, and cultural aspects affect operations and the battle space itself. Currently there are no Joint Information Operations and Information Assurance Concepts supporting the JOpsC.

### **4. Project Vision**

The vision begins by using Joint Prototypes and the IO Roadmap as springboards for the future. They will be used to design and drive the Information Operations project focus and instill in it the purpose, direction, and motivation required to meet and exceed the demands of effects based operations (EBO) out to 2015 and beyond. In implementing this vision all organizations must operate using initiative, flexibility, and agility at all levels. In some cases, this may require altering or re-engineering concepts and processes.

This concept will assume IO, along with intelligence and space assets, to be a core capability equivalent to land, sea, air, and special operations, in accordance with Defense Planning Guidance for FY 2004-2009. As USSTRATCOM has been designated the lead for development and production of the Overarching IO Concept, the efforts by USJFCOM J-9 will support and facilitate concept development and production, thus ensuring incorporation within the framework of the future Joint Operational Environment.

Establishment of a close, formal relationship between USSTRATCOM/Policy, Resources and Requirements and USJFCOM, J-9 will be through a signed Memorandum of Understanding. This will be critical to capture synergy and ensure complementary efforts.

### **5. Project Objectives**

The Supporting Joint IO Concept will as a minimum focus on three integrated IO functions across the full spectrum of conflict.

- IO will be capable of deterring, discouraging, dissuading, and directing an adversary, thereby disrupting his unity of command and purpose, while preserving our own.
- IO will protect our plans and misdirect those of the adversary, thereby allowing our forces to mass their effects to maximum advantage while the adversary expends his resources to little effect.



- IO will control adversarial communications and networks and protect ours, thereby crippling the adversary's ability to direct an organized defense while preserving effective command and control of our forces.

The concept will attempt to address these functions at the operational, trans-regional, and strategic levels while using the five core capabilities of electronic warfare (EW), psychological operations (PSYOP), operations security (OPSEC), military deception (MILDEC), and computer network operations (CNO). The related activities of public affairs (PA) and civil military operations (CMO) will also be addressed in this concept with other supporting capabilities such as logistics, intelligence, and space.

Finally, this concept will identify the requirements to integrate inter-agency capabilities, authorities, and functions with non-governmental organizations, academia, and industrial capabilities that are as yet untapped resources.

## **6. Links to COCOMs, RCCs, Services and Multi-national Concepts**

As approved by the Director, USJFCOM J9, the future Supporting Joint IO Concept development and experimentation will support the global and Joint IO communities. The operational requirements and basic concepts for IO will be derived during the front end analysis (FEA) of initial studies, lessons learned, and prior experimentation conducted with the Joint and JFCOM Staffs, Services, the Combatant Commands (COCOMs), and our multi-national Partners. Specific links with OSD, Joint Staff, STRATCOM's JFHQ-IO, CENTCOM, SOCOM and EUCOM will be established to capture lessons learned from recent operations in Iraq, Afghanistan, and elsewhere. EUCOM and JFCOM staff support to the approach is already strong. Our link with the NATO Military Interoperability Council (MIC) is an opportunity to learn and incorporate Coalition Information Operations concepts and lesson learned. MNIOE initiatives such as the Coalition and NATO Response Force Effects Based Operations will be incorporated in the IO concept development. These, in turn, are already supporting IO in the JFCOM MNE series. In our workshops, conferences, and meetings, we will lay the framework for the integration of Service, other government agency, and coalition concepts within the joint concept. This integration will result in global IO concept development and experimentation and thus, will refine the Joint IO concept and give greater insight to help develop service, coalition (to include NATO) and other government agency concepts. This approach is designed to support STRATCOM's development of an over-arching joint IO concept when they begin. In the interim, STRATCOM will be linked into all program activities and the products of joint and multi-national experimentation provided to STRATCOM IO developers. The JFCOM IO approach is also supporting the Army service IO concept development recently initiated.

## **7. Technical Approach**

The USJFCOM J-9 project will accomplish its objectives using a quality and functionally based process through research and implementation. The steps of this process include identification, validation, verification, and documentation of conceptual and functional requirements, discovery, hypothesis, and validation experimentation with transition of deliverables throughout. These efforts will culminate in validation experimentation of the final concept.



The vehicles will be Front End Analysis (FEA), wargames, lessons learned and Limited Objective Experiments (LOE) in FY04 to develop the US concept followed by a similar cycle to support NATO concept development in FY05 and FY06. The project will be enhanced and supported by limited experiments with a focus on identifying potential actionable recommendations and improvements to existing processes and emerging prototypes (Standing Joint Force Task Force Headquarters, Joint Inter-Agency Coordination Group, etc.) throughout. This process will rapidly provide innovations to support hypothesis testing of mature concepts as well as on-going IO related actions in the Department of Defense (DoD) IO Roadmap.

## **8. Integration Strategy**

The Supporting Joint IO concept will be developed using a disciplined approach that utilizes a concept development team, users and Subject Matter Experts (SMEs). To achieve the desired end-state, the project will define the optimum configuration in terms of process, capabilities, doctrine, personnel, training and equipment with particular emphasis on integration of and co-evolution with future Joint, coalition, and inter-agency future Information Operations concepts. The near-term end-state is to develop IO concept version 1.0 for input to existing JOpsC and enabling concepts by 1 October 04.

## **9. Experiments**

The hypotheses developed for the Supporting Joint IO Concept will be tested and refined through a series of experiments prior to a military utility assessment. International experimentation (coalition, NGO, corporate) will be carried out both remotely and centrally.

Experimentation will commence in FY04 with limited concept events that address the common lexicon of terms, cross-walking concepts, and refining the overall approach for the concept. These will be supported by additional service, coalition, and inter-agency wargames and experiments JFCOM will co-sponsor.

## **10. Measures of Success**

The Supporting Joint IO Concept must demonstrate the effectiveness and suitability of processes and capabilities to support effects based operations. These include implementing future operational and enabling concepts to plan, direct, and control the resources and assets available to achieve desired effects. This must include quantifiable and qualifiable improvements to IO and the ability to plan, execute, and assess the results of all IO concepts in an effects-based context. The project's Critical Operational Issue (COI) is "To what extent does the new IO concept improve service, joint, coalition and inter-agency IO in the future operational environment?" USJFCOM, as the Transformation lead, has the task of reporting the effectiveness of the IO concept.

In order to determine the level, to which the program answers the COI, the IO concept must successfully demonstrate the capability to satisfy the predetermined Measures of Effectiveness (MOE) and associated Measures of Performance (MOP). These measures form the basis of the



JFCOM operational assessment of military utility strategy. The JFCOM J9 Analysis Division partnering with other service, joint, coalition, inter-agency and non-government analysis, will perform both technical and operational assessments.

## **11. Training**

The appropriate level of training will be provided to personnel involved in all experiments to ensure the results are not distorted by a lack of proficiency in either the concept or the supporting systems and processes. Training will be required, particularly during the experimental process, as the concepts, capabilities, and systems evolve. The project team will evaluate the effectiveness and efficiency of the training modules developed and presented. This evaluation is conducted to determine whether incorporation into service, joint, coalition and inter-agency training programs is appropriate. As concepts and experiments for IO are developed, a detailed training plan synchronized to applicable experiments will be developed, bi-laterally coordinated, and published as an update to the overall project management plan.

## **12. Participating Organizations**

As appropriate, participating organizations will include representation from all Services, joint, coalition, inter-agency, Non-Government Organizations (NGO), academia and corporate representatives. It will vary by event. The co-sponsors and IO core team will determine the exact composition in each event as specific experiments are identified and integrated into the project management plan.

## **13. Organizational Approach**

The USJFCOM J-9 IO project will use a series of management layers and bodies to facilitate product development. The adoption of such a management structure ensures success for the program

- Senior Steering Group
- Project Management Team
- IO Concept Development Team
- IO Core Management Team
- Interagency Workshop
- MNIOE Workshop

### **Senior Steering Group**

The Senior Steering Group (SSG) will be composed of the sponsoring Regional Combatant Commands (RCCs), Functional Component Commands (FCCs) and Senior Mentors. Responsibilities will be to provide program direction to ensure the IO concept remains properly focused and evolve to support future operational capabilities required.

This group is briefed bi-annually or as required to provide senior level guidance and resolve issues involving funding, functionality, and competing RCC, FCC, and service requirements. In addition, this group will receive quarterly status reports from the Project Manager.



## **Project Management Team**

The IO Concept will be lead by a designated, full-time Project Manager (PM) and a designated, full-time Deputy Program Manager (DPM). They will both work directly for the JFCOM J9 Chief, Space and Decision Superiority.

The Project Managers (PM/DPM) will have overall responsibility for project budget, schedule, and performance, as well as overall responsibility for programmatic coordination activities of the program. They will be the primary interface with core management, technical, experimentation, evaluation, modeling and simulation, prototype and operational participants as well as the Services and external organizations.

The PMs will ensure coordination between concept developers, partners and users. It will be responsible for ensuring consistency between the standards adopted for the IO concept and those in current JOpsC Operational and Enabling concepts as well as those under development.

## **Concept Development Team**

The IO Concept Development Team (CDT) will be comprised of Subject Matter Experts, Action Officers from participating organizations and others responsible for success of the IO Concept. Composition will be developed based on project plan coordination and requirements, and then adjusted as required through project execution.

The CDT will be responsible for day-to-day operations in the development, support and execution of the project plan, to include all experimentation and analysis. This group will be responsible for the successful design, development, coordination and execution of the project from inception through concept development and experimentation to transition. The CDT will provide inputs, comments and reports to the Project Manager as directed.

## **IO Core Management Team**

The IO Core Management Team is an internal USJFCOM body of twenty-five Action Officers responsible for IO related activities within the Unified Command. USJFCOM J9 Space and Decision Superiority and the J35, Chief of Future Operations will co-chair the group. The mission is to share information for better situation awareness of short-term and long-term related IO activities. The IO Core Management Team will also serve as a coordination body for feedback on IO concept development and experimentation, supporting issues, experiments and actions. They will meet on a quarterly basis.

## **Interagency Workshop**

IO is a constant challenge of integration, coordination, and synchronization, especially for interagency action and feedback. USJFCOM J9 IO Project Management Team will work through CJCS, J39/DDGO to host an Interagency Workshop. This forum will serve as a vehicle for interagency collaboration, coordination, and integration of Joint IO concepts, National and Military Policy, and Rules of Engagement that will impact IO.



## **Multi-National IO Experiment (MNIOE) Workshop**

USJFCOM J9 has achieved great success with multi-national (MN) participation and continuous engagements through MNIO initiatives and workshops. Our link with the Military Interoperability Council (MIC) provides an excellent opportunity to learn and incorporate Coalition Information Operations concepts and lesson learned. MNIOE initiatives such as the Coalition and NATO Response Force Effects Based Operations will be incorporated in the IO concept development. These, in turn, are already supporting IO in the JFCOM Multi National Experiment series. It can be expected that a derivative of the US National IO Concept will be adopted by our allies.

### **14. Deliverables**

#### **Concept Version 1.0 – Describes and scopes a specific future warfighting problem and potential solutions.**

The purpose of the first version is to (1) identify novel systems, concepts, organizational structures, and technologies as potential solutions to specified warfighting problems, (2) provide a framework for Actionable Recommendations, Functional Concepts, and Transformation Roadmaps, and (3) provide a conceptual and capabilities framework for further concept refinement and higher fidelity experimentation.

It will be composed of a description of the operational environment, identification of future military problem to be solved, proposed solution(s), required tasks, required capabilities, and examples of ideas in action.

Version 1.0 will be derived from discovery experimentation, lessons learned from current and recent real world operations, and historical analysis. Discovery experimentation will typically be conducted as a low level of fidelity (seminars, table top wargames, etc.) This will include the staffing of ideas across the Joint community.

#### **Concept Version 2.0 – Presents an experimentally refined solution set to the identified warfighting problem. Also, sets conditions for follow-on high fidelity experimental assessment.**

The purpose of the second version is to (1) support the development of actionable recommendations and transformation change packages through experimentally refined hypotheses, (2) provide experimentally refined capabilities in support of Functional Concept and Transformation Roadmap development, and (3) set the stage for follow-on high fidelity hypothesis assessment experimentation.

It will be composed of version 1.0 plus the following: experimentally assessed statements of cause and effect relationships between the identified military problem, proposed solution, and required capabilities (with metrics); refined identification of how to achieve required capabilities; the resolution and details needed to immediately start prototyping the effort, if directed; and the associated CONOPS for specific scenario(s).



Version 2.0 will be derived from hypothesis refinement experimentation, lessons learned from current and recent and real world operations, and historical analysis. Hypothesis refinement experimentation will typically be conducted at a medium level of fidelity (i.e. M&S supported wargames).

**Concept Version 3.0 – Provides experimentally assessed solutions and required capabilities.**

The purpose of the third version is to (1) support the development of actionable recommendations and transformation change packages through experimentally assessed cause and effect relationships between military problems and identified capabilities, (2) identify high value potential prototype efforts, and (3) provide experimentally assessed capabilities in support of Functional Concept and Transformation Roadmap development.

It will be composed of version 2.0 plus the following: experimentally assessed statements of cause and effect relationships between the identified military problem, proposed solution, and required capabilities (with metrics); refined identification of how to achieve required capabilities; the resolution and details needed to immediately start prototyping effort, if directed; and associated CONOPS for specific scenario(s).

Version 3.0 will be derived from hypothesis assessment experimentation, lessons learned from recent and current real world operations, and historical analysis. Hypothesis assessment experimentation is typically conducted at a high level of fidelity (lab settings, field experiments, etc.) to explore alternative cause and effect patterns and sets of limiting conditions.

## **15. Organization and Staffing**

Overall responsibility for management of the Supporting Joint IO Concept will reside with JFCOM J9, Space and Decision Superiority Department. Key to IO concept development is the temporary assignment of functional and technical staffs from internal and external to JFCOM to jump start the concept development process. This will be necessary until full-time positions are filled with personnel to provide the critical institutional knowledge and subject matter expertise. With strong relationships and participation from all Services, joint, coalition, inter-agency, and Non-Government Organizations representatives, the IO Concept Development Team is well-positioned to successfully develop and integrate the conceptual framework for Information Operations to support the future force. The organization framework and proposed staff expertise is shown in figure 1.

Initially, this organization will be small and draw upon the resources of other Divisions. However, upon completion of JOpsC prototype and enabling Concepts integration, approximately 1 OCT 04, the IO Cell should become robust and representative of every capability of IO, while also possessing liaisons from related activities, and critical interagency players.



## 16. Equipment and Facilities

It is essential that equipment and facilities be taken into account, not only workspace and equipment requirements for personnel, but also the communications and networks requirements for experimentation. Workspace and seating requirements internal and external to a Special Compartmentalized Information Facility (SCIF) and a Special Technical Operations facility (STO) will be requested for temporary and permanent personnel. In addition, equipment supporting Joint Warfighting Intelligence and Communications System (JWICS), Joint Interactive Analysis and Planning Capability (JIAPC), Special Access Programs (SAP), Restricted Handling Caveats, and Information Warfare Planning Capability (IWPC) are required for experimentation. The assessment by Systems of Systems Analysis (SOSA) staff also will be required to meet anticipated networks and infrastructure requirements.

Further, it should be expected that the IO Staff will expand and contract as experts external to the command are brought in temporarily to achieve specific objectives associated with concept development. While much of the effort will be accomplished “virtually” by teleconferencing and internet, brainstorming sessions must still be accomplished through face-to-face meetings.

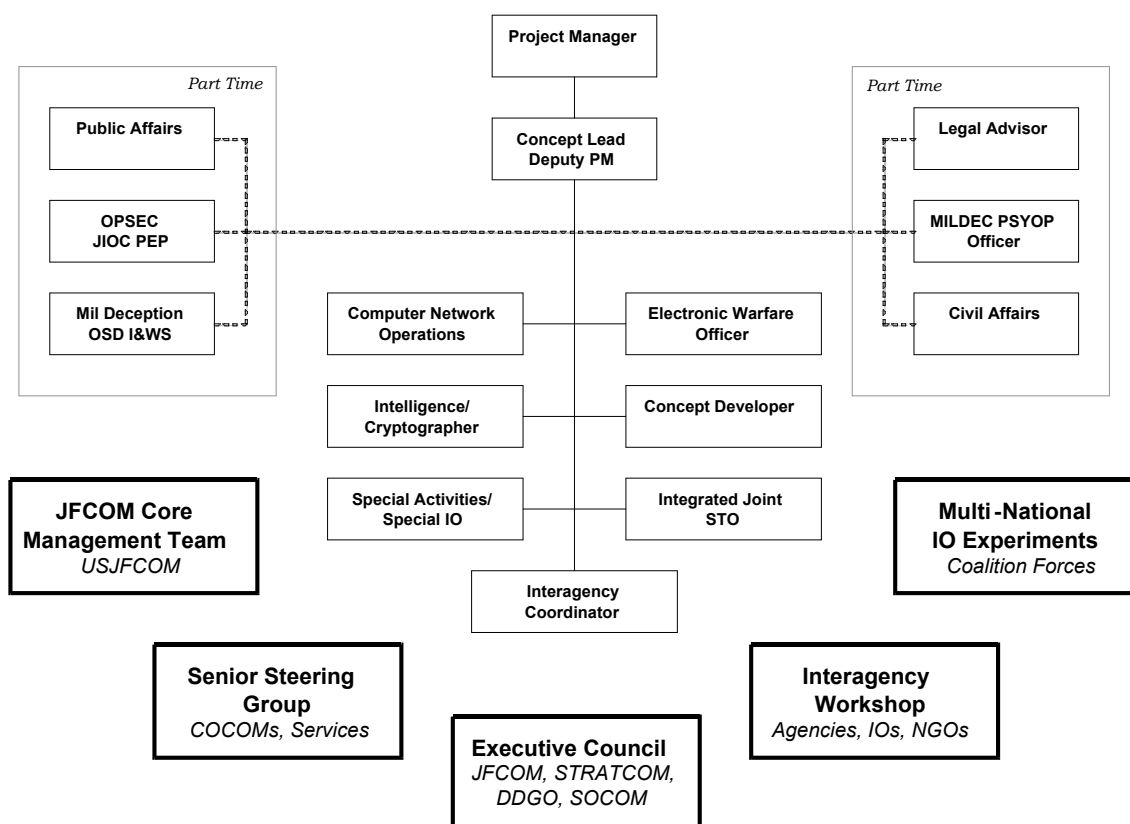


FIGURE 1 – Organizational Framework and Staffing Requirements



## 17. Project Timeline

The overall USJFCOM J-9 project will be a 36-month effort. The first 12 months will consist of detailed Front End Analysis (FEA) supported by discovery experimentation and developing the over-arching joint concept. It will accelerate opportunities to accelerate joint, service, coalition and inter-agency future concepts. Hypothesis development, testing, and validation during the following 24 months (FY05 and FY06) will culminate in transition to prototyping. Figure 2 shows the proposed schedule by phase with planned meetings/collaboration, participation in key events, and project deliverables.

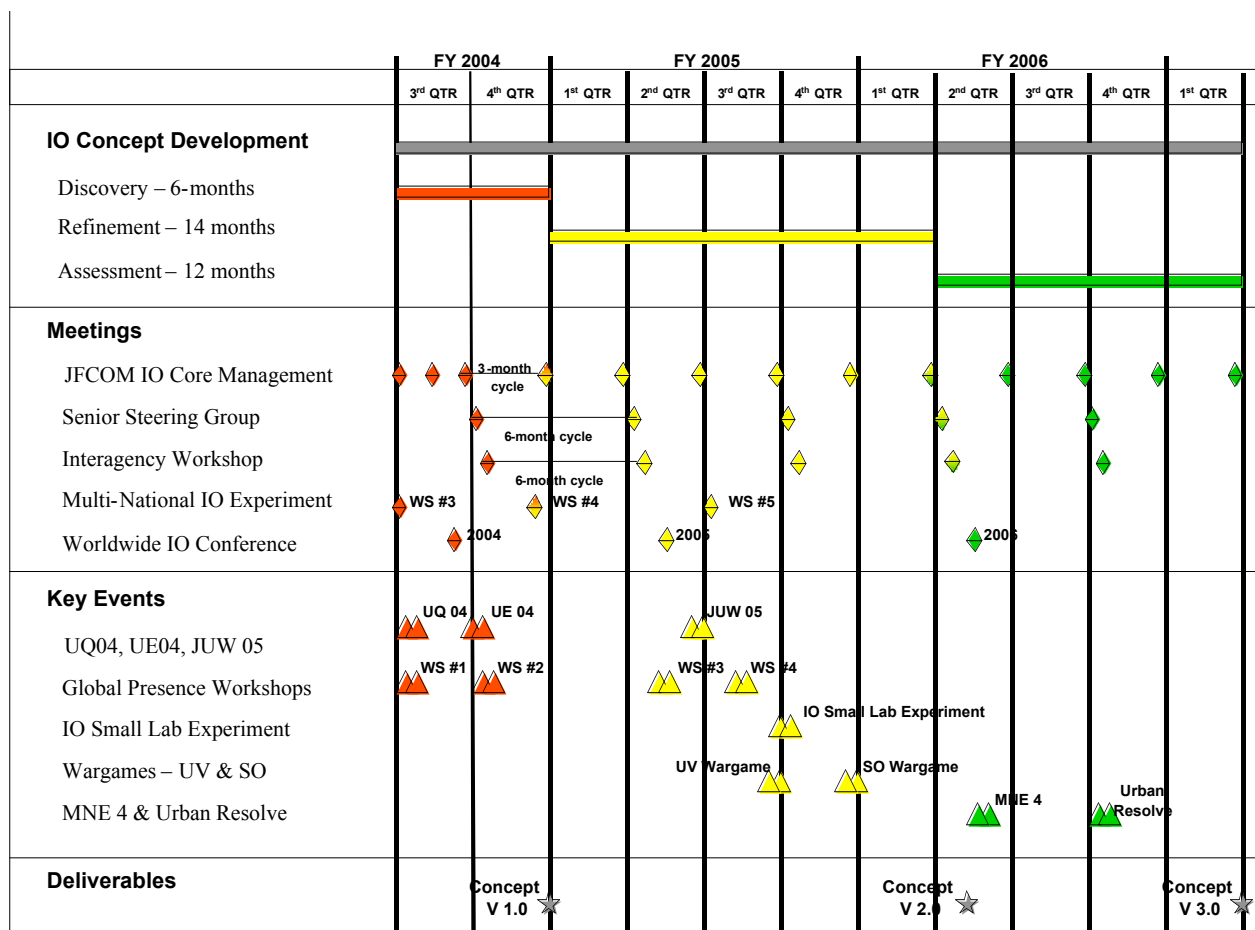


FIGURE 2 – Projected IO Concept Development Timeline



## **Global Information Integration and Decision (GIID) Portfolio**

**Peter M. Trask  
Christine Salamacha  
Michael Cramer**

The Johns Hopkins University Applied Physics Laboratory

The Global Information Integration and Decision (GIID) Portfolio is a multi-year initiative to demonstrate and transition an integrated portfolio of capabilities in strategic and national command and control (C2), consistent with DoD's transformation to net-centric operations and warfare. Working with established programs and new initiatives, the Portfolio will provide cross-domain orchestrated services based on U.S. Strategic Command (USSTRATCOM) Global C2 needs. Each program and initiative will provide web-based services and expose data in a "services oriented architecture." The Portfolio will leverage DoD's net-centric core services.

The GIID Portfolio initiative will provide incentives for legacy programs to develop net-centric implementations. It will establish an ontology, taxonomy, and data model for the missile warning and defense community and will extend them to other communities in subsequent years. In the short term, the GIID architecture will require legacy systems to expose data and services, while they maintain parts of their legacy system architectures. The long term goal is an architecture where new developments are consistent with the Global Information Grid (GIG) systems engineering and net-centric data strategy.

The principal sponsors of the GIID portfolio are Office of the Assistant Secretary of Defense, Networks and Information Integration and USSTRATCOM. Programs in the initial GIID portfolio include:

- Command and Control of Ballistic Missile Capability (C2BMC)
- Combatant Commander's Integrated C2 System (CCIC2S)
- Defense Strategic Integrated Decision Environment (DSIDE)
- Fused Battlespace View (FBV)

The authors would like to acknowledge the contributions of Tom McNamara and Janet Spedden from the Johns Hopkins University Applied Physics Laboratory for definition of the GIID Portfolio. Other organizations making significant contributions to definition of the GIID Portfolio are Lockheed Martin, The MITRE Corporation, FGM, Inc., National Security Research (NSR), and the Defense Information Systems Agency (DISA).



# ***Global Information Integration and Decision (GIID) Portfolio***

## ***Sixth Annual ONR / CADRC Decision Support Workshop***

*Peter M. Trask  
The Johns Hopkins University  
Applied Physics Laboratory*

*9 September 2004*



## **Outline**

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- **GIID Portfolio**
- **Expedient Community of Interest (ECOI) Services**





## GIID Portfolio Overview

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- **A multi-year portfolio plan**
  - 4 Funded in FY05 by Horizontal Fusion
- **Focus on Strategic and National C2**
  - 4 Fill gaps in selected mission threads
  - 4 Identify and resolve overlaps
- **Support DoD transformation to NCOW**
  - 4 Consistent with DoD Net-centric data strategy
  - 4 Leverage NCES
- **Evolve legacy systems to net-centric SOA**
  - 4 Publish authoritative data
  - 4 Expose functions as web services



## GIID Stakeholders

---

- **Portfolio sponsors**
  - 4 OASD (NII) C2 Policy
  - 4 USSTRATCOM
- **Program sponsors**
  - 4 USSTRATCOM – *D-SIDE, FBV, I-SPAN*
  - 4 MDA – *C2BMC*
  - 4 USAF, ESC – *CCIC2S*
  - 4 NAVAIR – *Mobile Command Element*





## The GIID Portfolio Approach

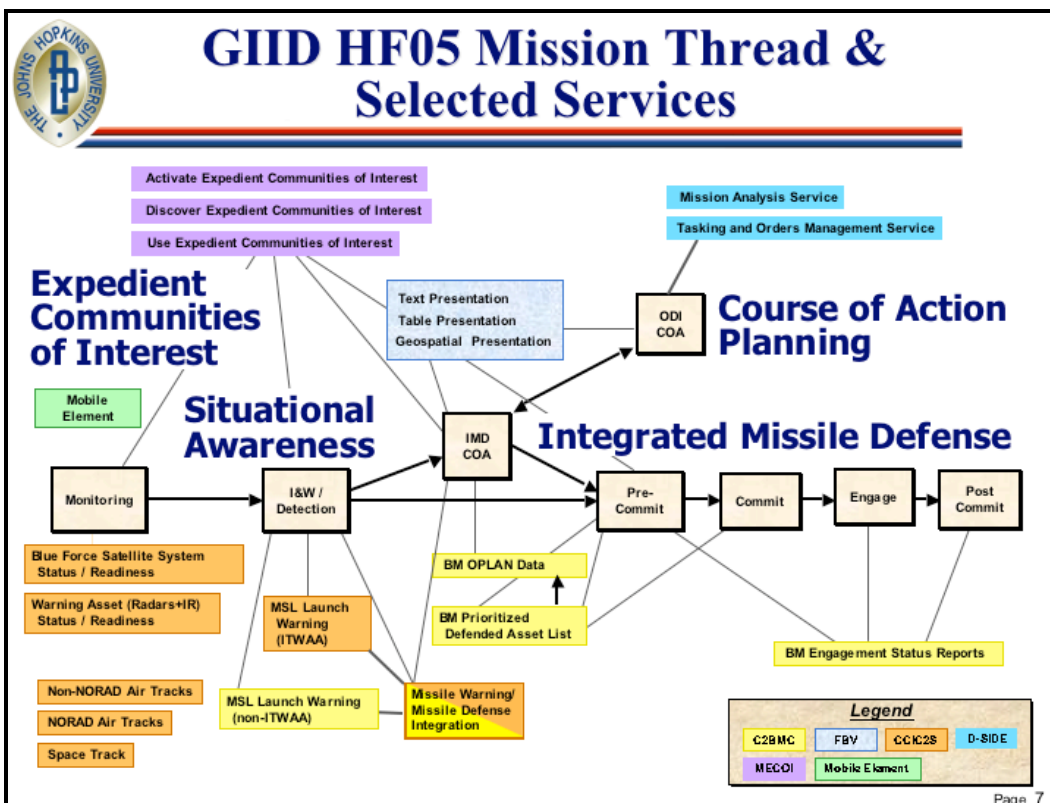
- Define global C2 capabilities required for strategic reference mission(s) & scenarios
- Establish a 'portfolio' of services from existing C2 programs of record that fulfill defined capabilities
  - 4 Avoids stovepipe focus
  - 4 Shifts focus from programs/platforms to capabilities
- Leverage Net-Centric initiatives (e.g. GIG, NCES)
- Capture portfolio lessons into guidance, policy, doctrine, standards for broader domain application
- Requires strong warfighter support to advocate and support portfolio efforts



## GIID Architecture Evolution

- **Objective:** Develop an architectural approach leveraging NCES and SOA for integration of services provided by the various C2 programs.
- **Short-Term Approach:**
  - 4 Examine legacy system architectures to find opportunities to integrate at multiple levels and expose services
  - 4 Expose information based on shared ontology
    - *Wrappers, XML, meta-data tagging*
  - 4 Support "post before process"
- **Long-Term Approach:** Evolve to an architecture where independent development is consistent with GIG systems engineering
- Establish ontology and data model to provide consistent basis of communication

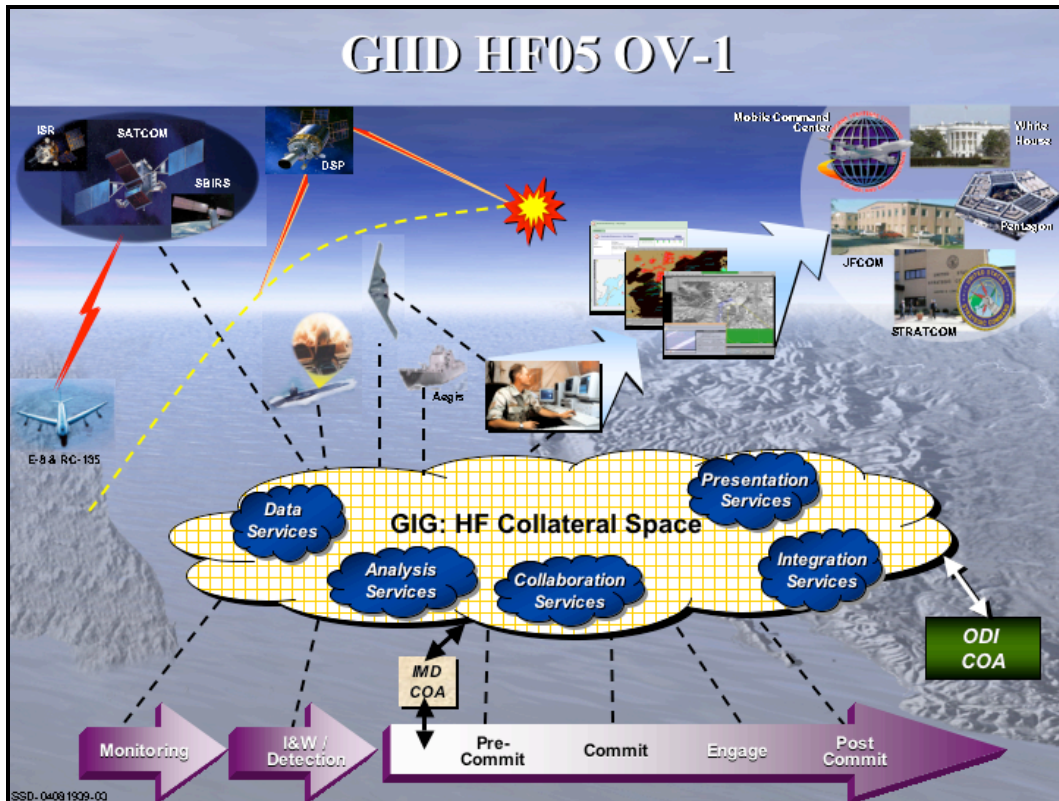





## GIID HF05 Services

Blue Force Satellite Status/Readiness	IMD
Warning Asset (Radars+IR) Sts & Readiness	
Missile Launch Warning (ITW/AA)	
Missile Launch Warning (Non-ITW/AA)	
Missile Warning/Missile Defense Integration	
BM OP Plan Data	
BM Engagement Status Reports	
BM Prioritized Defended Asset Lists	
NORAD Air Tracks	Post Before Process (for IMD)
Non-NORAD Air Tracks	
Space Tracks	
Text, Table, & Geospatial ODI Display	GIID MARS Portal
Mission Analysis Service	COA Development
Tasking and Orders Management Service	Integration w/ GS Plans
Activate Expedient Communities of Interest	ECOI
Discover Expedient Communities of Interest	
Use Expedient Communities of Interest	







## Outline

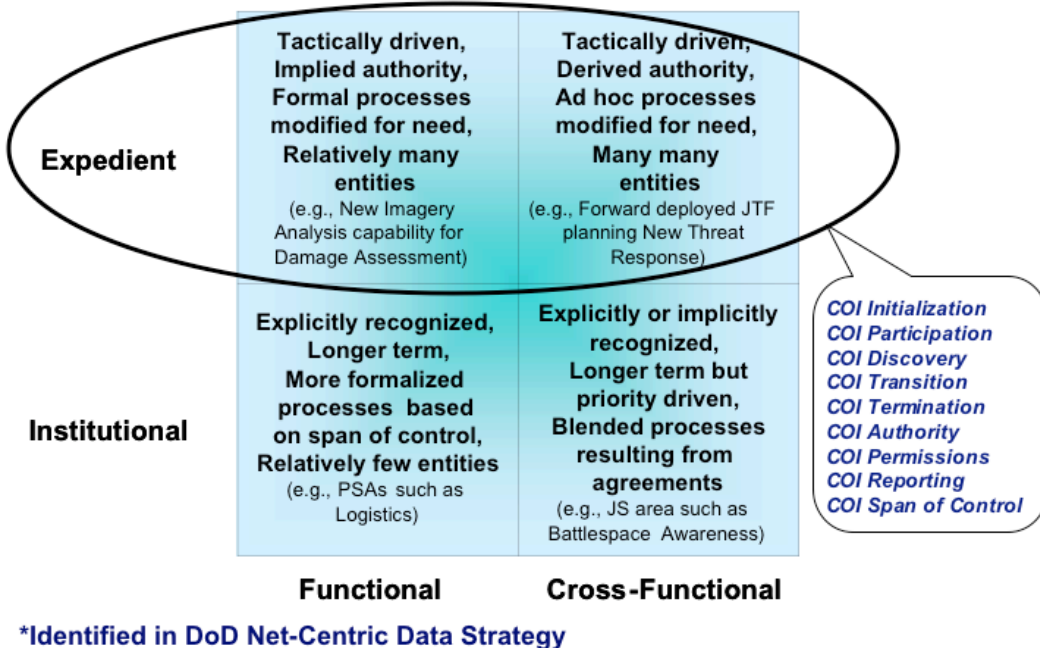
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- **GIID Portfolio**
- ➡ • **Expedient Community of Interest (ECOI) Services**





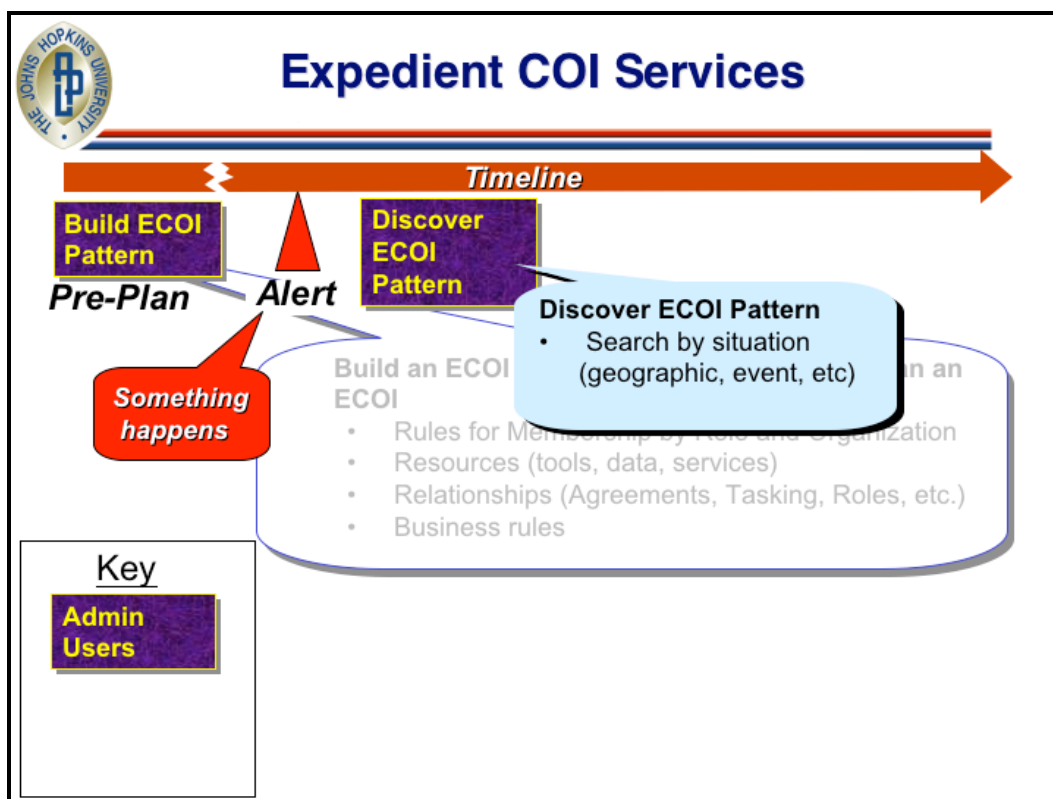
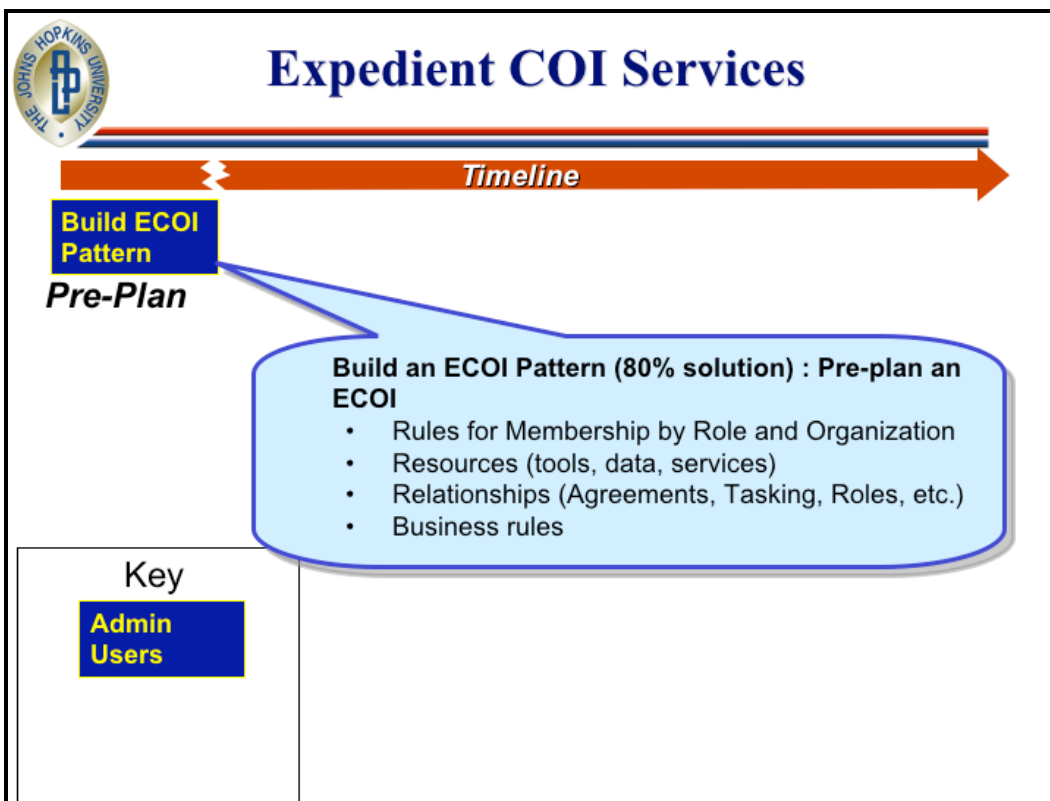
## Types of COIs\*



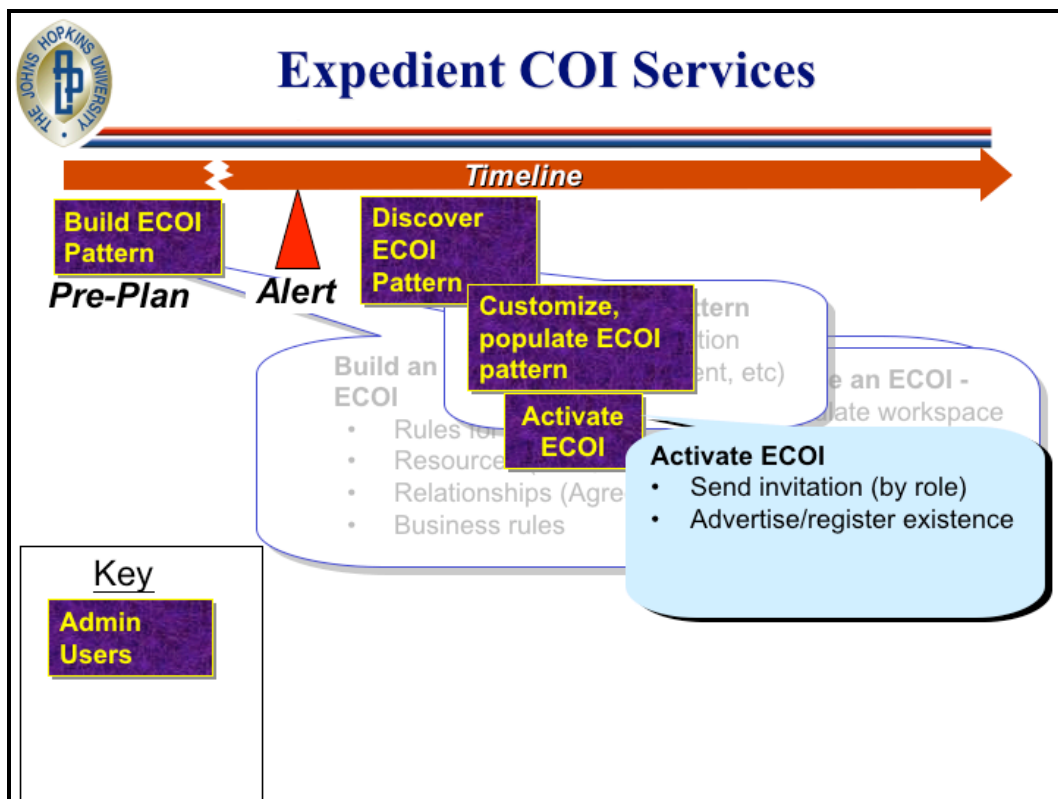
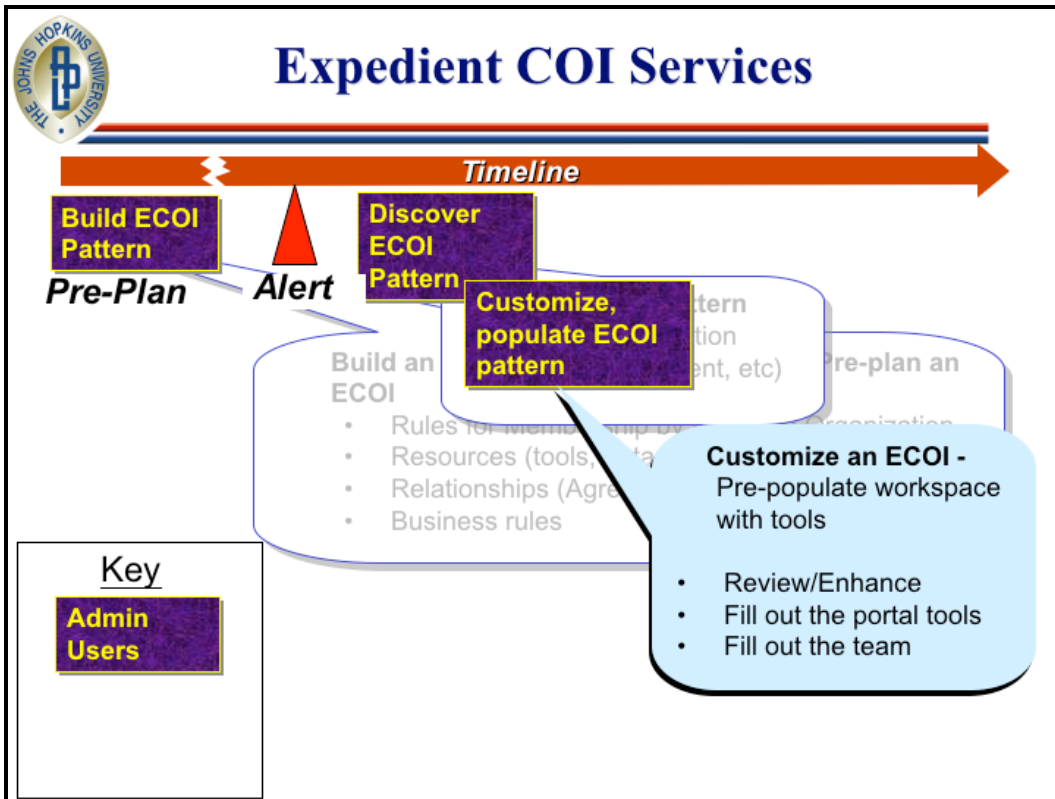
## Expedient COI Services

- ECOL services enables expedient operational Communities of Interest (COIs) to be formed quickly in response to crisis situations
- ECOL services include:
  - 4 Quickly establishes COI membership, relationships, roles, business rules to meet the demands of the moment
    - *Emphasis on crisis response, mission-focused support*
  - 4 Populates a customized COI environment (views, tools)
  - 4 Leverages standing COIs and established tasking relationships
    - *Use of COI templates or patterns*

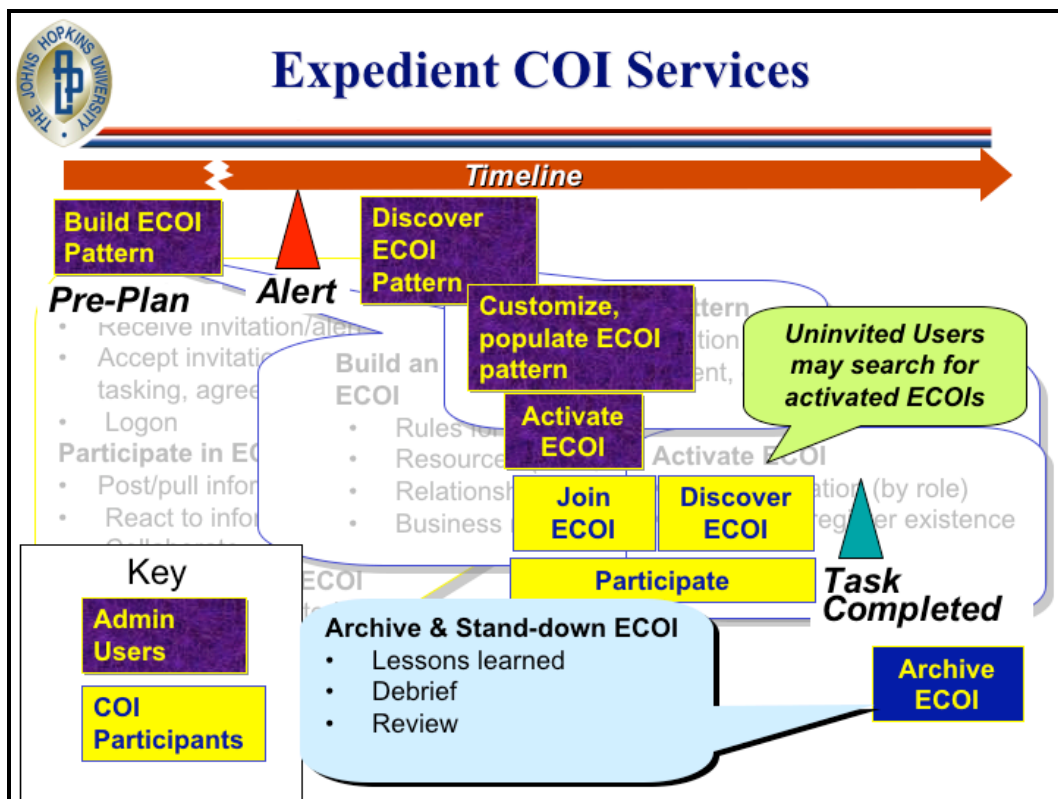
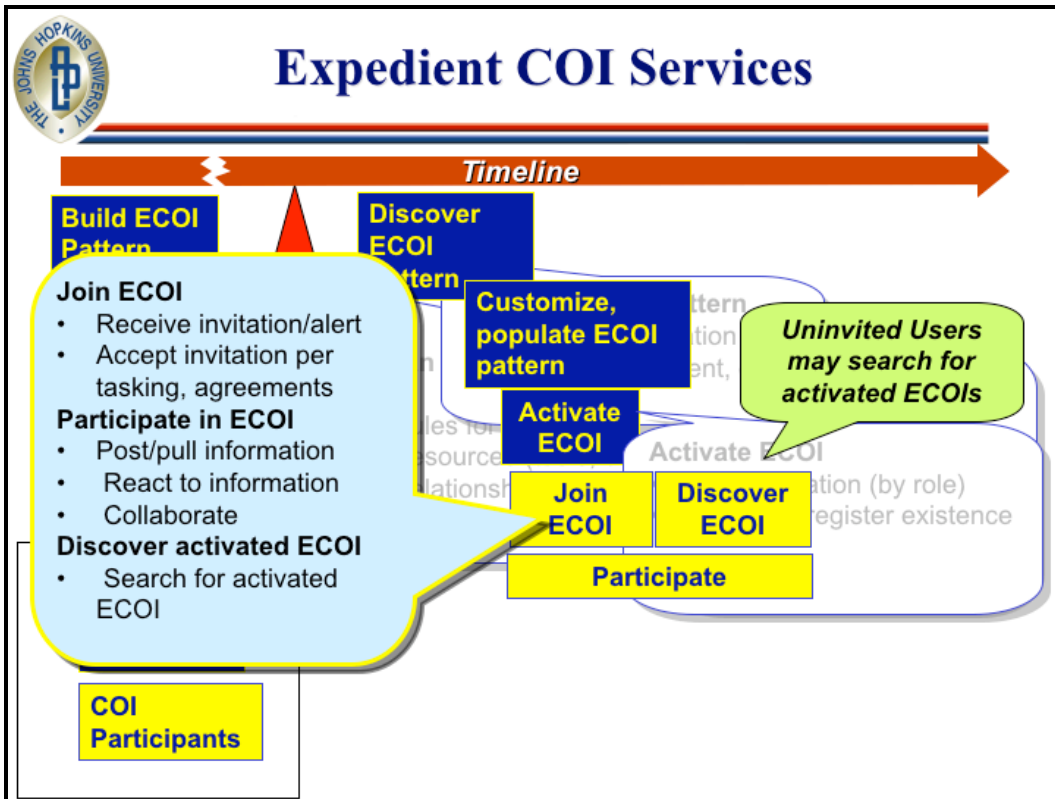










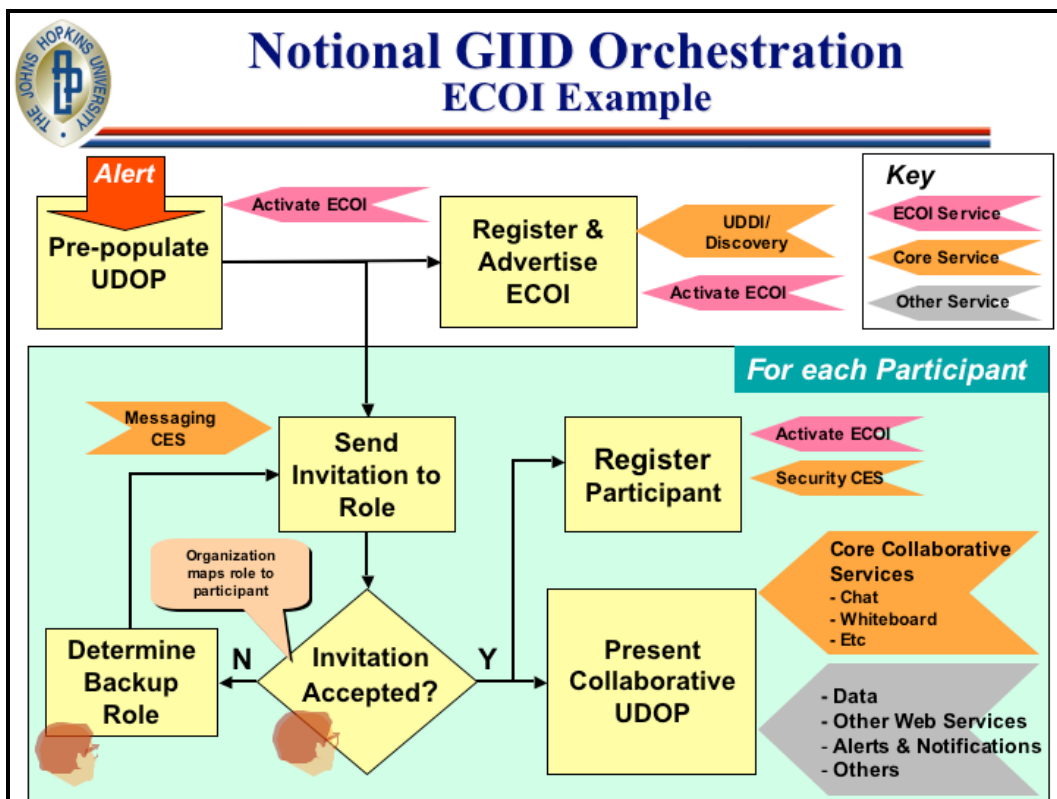






## Web Service Orchestration in the GIID

- **Encode Business Rules and Workflow**
  - Allow run-time variations based on operator actions, alerts, or changes in environment
- **Control Interactions between Web Services**
- **Execute Asynchronous and Long-Running Processes**
- **Operate in the context of an Orchestration Engine**
- **Example:**
  - 4 Aggregate data from multiple web services
  - 4 Transform, e.g. changes in units, or map between schemas
  - 4 Provide value-added web service or display







## GIID HF05 Portfolio Summary

---

- **Focus is Strategic and National C2 enablers and net-centric transformation**
  - Missile Warning/ Defense integration at the data level
  - Maintain link to Global Strike via coordinated COA planning
- **Capabilities met through services offered by legacy programs**
  - Publish legacy data
  - Legacy C2 functions/applications exposed as services
  - 17 Services from 6 PORs
- **Key Stakeholders:**
  - OASD (NII), USSTRATCOM, MDA, USAF ESC, NAVAIR



  
IBM Software

## Sixth Annual ONR / CADRC Decision-Support Workshop




“Interoperability Levels”

Dr. Peter Bahrs, Distinguished Engineer  
Dr. Chris Codella, Deputy CTO

September 8-9, 2004, Quantico, Virginia

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IBM Software

## Introduction - Best Practices

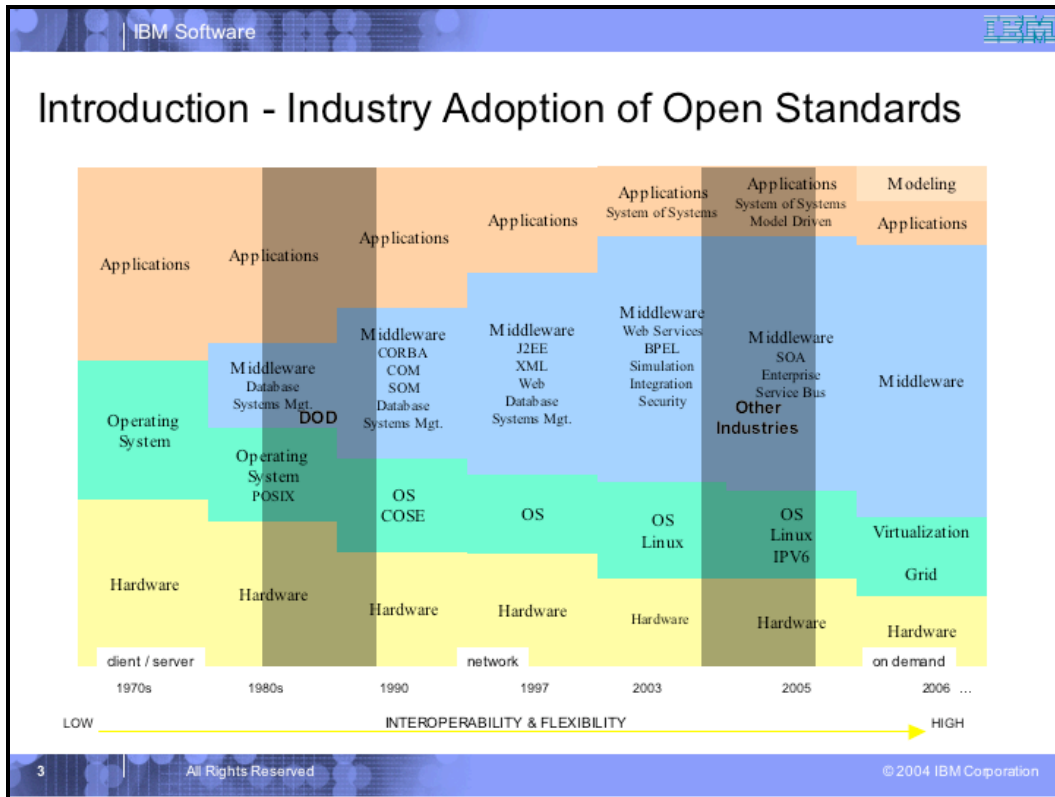
- **This presentation is based on many years of experience with 1000s of customer projects**
- **Interoperability is mainstream in other industries; evidenced by partnerships, standards development and COTS maturity**
- **Interoperability is:**  
  
“Enabling business, systems, and people to share development artifacts, runtime information and common operations.”
- **Open Standards are a key to successful interoperability**
  - Successful open standards are those that are widely accepted across industries and have significant commercial investment

2

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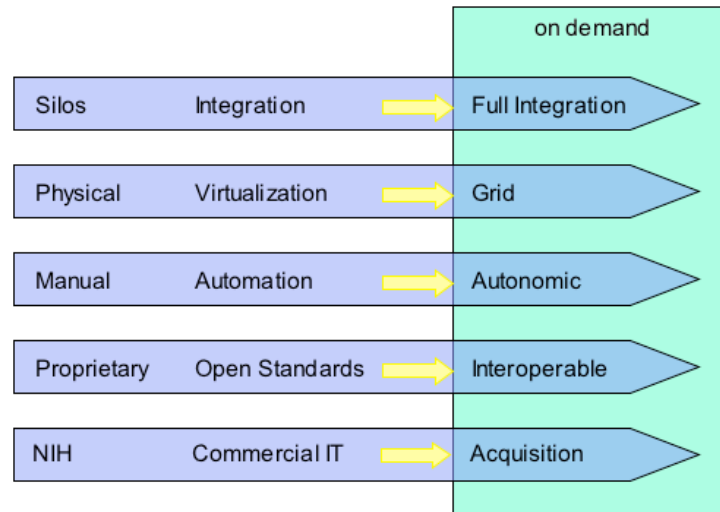
## Introduction - Interoperability Challenges

- Can I react quickly enough to opportunities or threats to my environment?
- Can I create new mission capabilities from my existing systems?
- Can users react in real-time to the most recent information?
- Can I easily access information anytime, anywhere with my choice of device?
- Are my business operations integrated end-to-end for optimal efficiency?
- Can I decrease expense while providing more function?

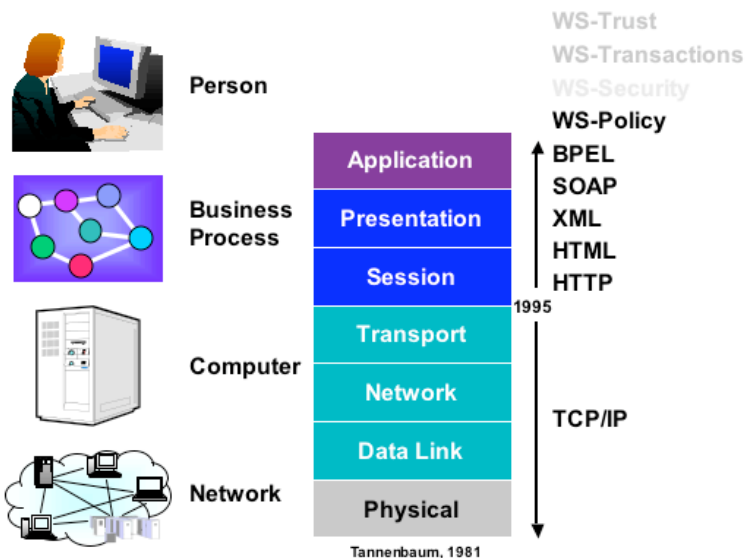
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## Introduction - Strategy



## Introduction - The Next Internet Protocol Stack



### A New Programming model and computing platform is emerging

- Based on collections of web services (not networks of computers)
- Complex sets of distributed services will appear as though they exist and run on a single "machine" - a virtual computer
- A runtime environment will be required to support the semantics and expectations associated with this new programming model



## Anatomy of a System



### Determinism

- Real Time
- Soft Real Time
- Time Sharing

### Information

- Message Router
- Pub / Sub
- Service Bus
- Transformation
- Federation

### Awareness

- Autonomic
- Event analysis
- Provisioning

### Service Oriented

- Publish
- Discover
- Access

### Nodal Complexity

- Sensor
- Actuator
- Control system
- Radio
- Workstation
- Server
- Broker
- Cluster

### Processing

- Process Modeling
- Workflow
- Transactional

### Operations

- Deployment
- Change
- Monitoring
- Management
- Recovery

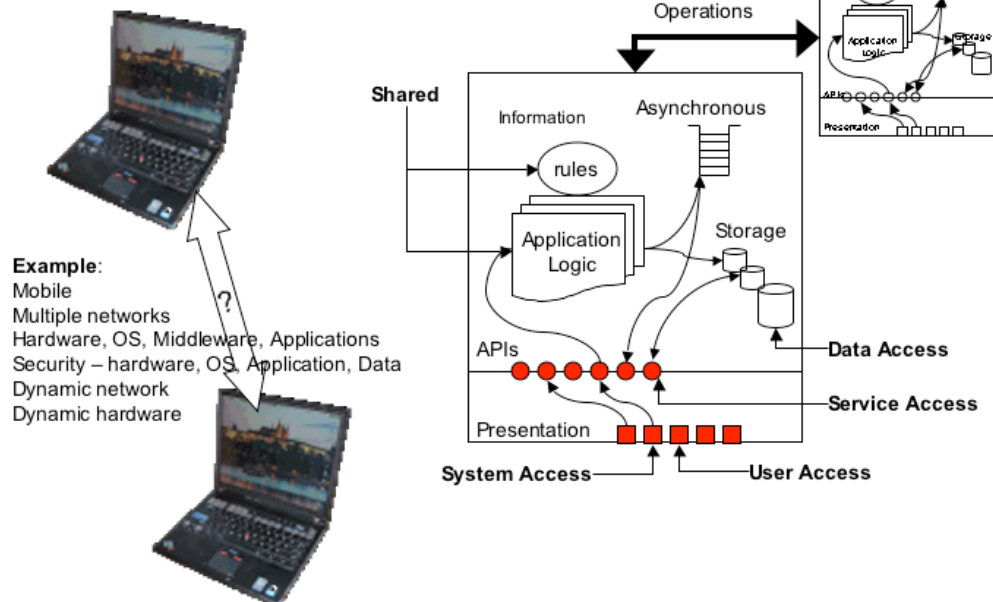
### Lifecycle

- Requirements
- Architecture
- Simulation
- Design
- Development
- Build
- Testing
- Standards
- Integration
- Classification
- Security
- Policy
- Culture

### Non Functional:

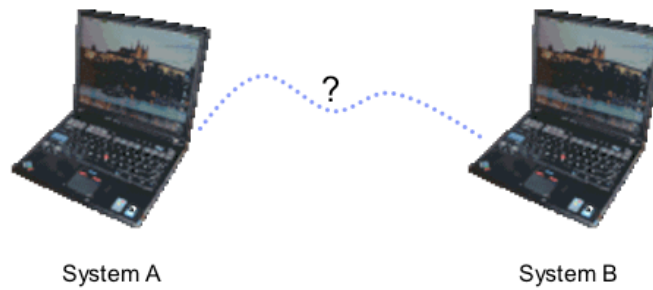
- Performance
- Security
- Throughput
- QOS
- SLA
- Users
- Volumes

## Anatomy of an IT system (cont.)



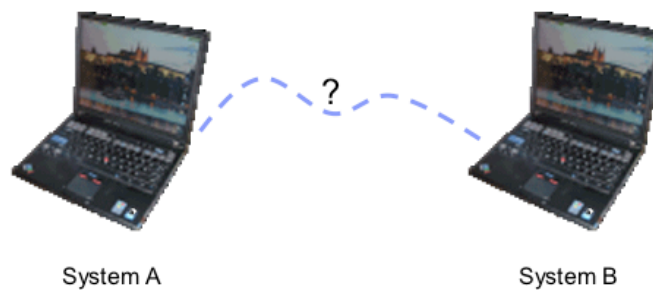


## Level 1 – network connectivity



Physical: Ethernet, Token Ring, Router, Bridge, etc.

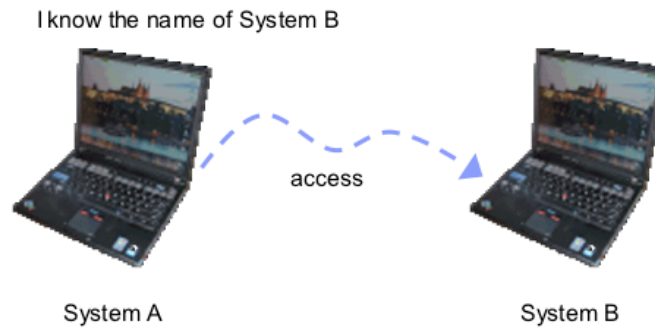
## Level 2 – network protocol



Protocol: TCP/IP, 802.11, NETBIOS, Open Standards, etc.



## Level 3 – static discovery



Names are static, hard coded, finite, not scalable.

## Level 4 – dynamic discovery

Discover systems

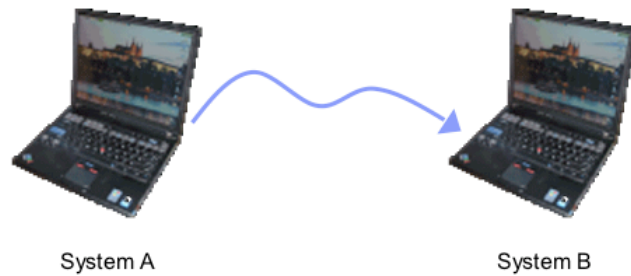
I found the name of System B and access it.

Names are dynamic, lookup performed, name or location found, scalable, Open Standards.



## Level 5 – guaranteed delivery

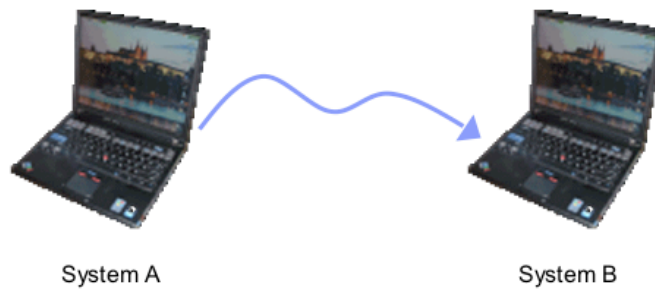
When I send XYZ, it is guaranteed to get there.



Logged, traceable, transactional, Open Standards.

## Level 6 – information

When I send XYZ, System B understands and expects it.

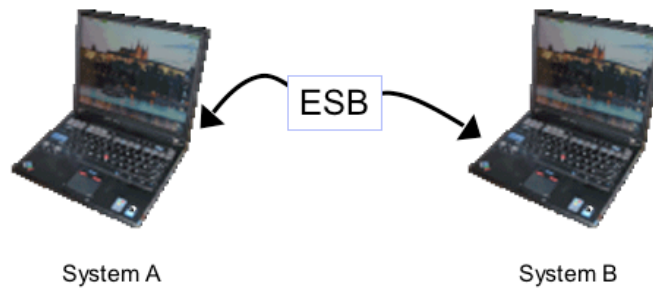


Industry data models, schemas, Open Standards.



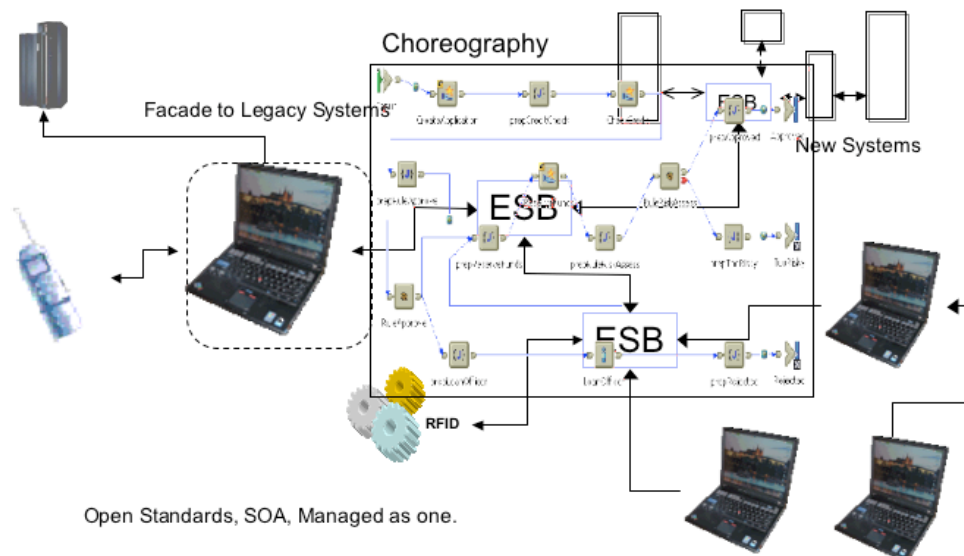
## Level 7 – enterprise service bus

I send information via another system.



Open Standards, SOA, guaranteed delivery, multiple protocols, heterogeneous systems.

## Level 8 – mega systems



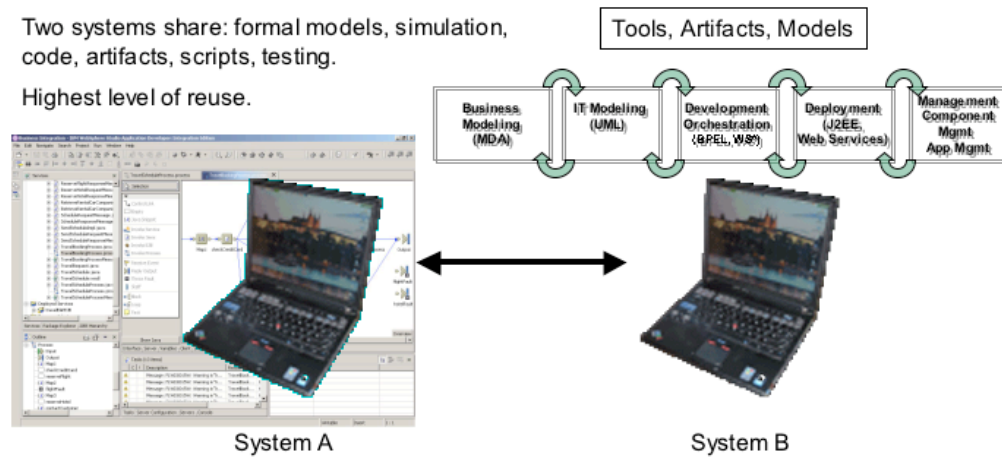
Open Standards, SOA, Managed as one.



## Level 9 – lifecycle

Two systems share: formal models, simulation, code, artifacts, scripts, testing.

Highest level of reuse.



## Level A – Visual

System Access

Presentation Services



System A



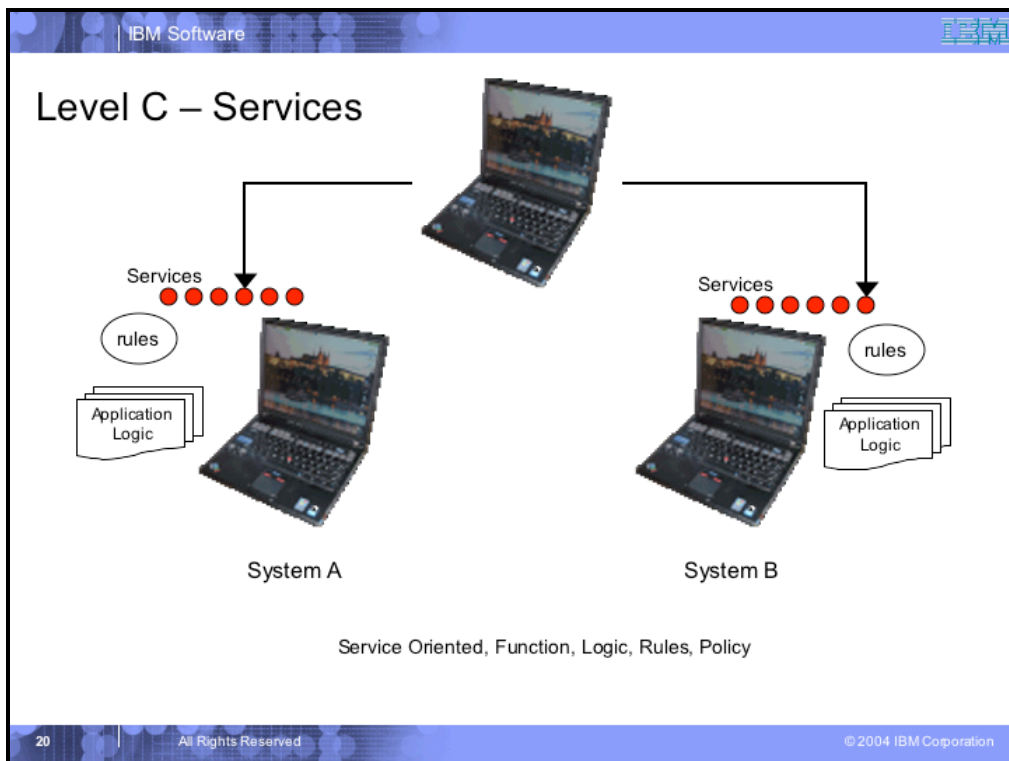
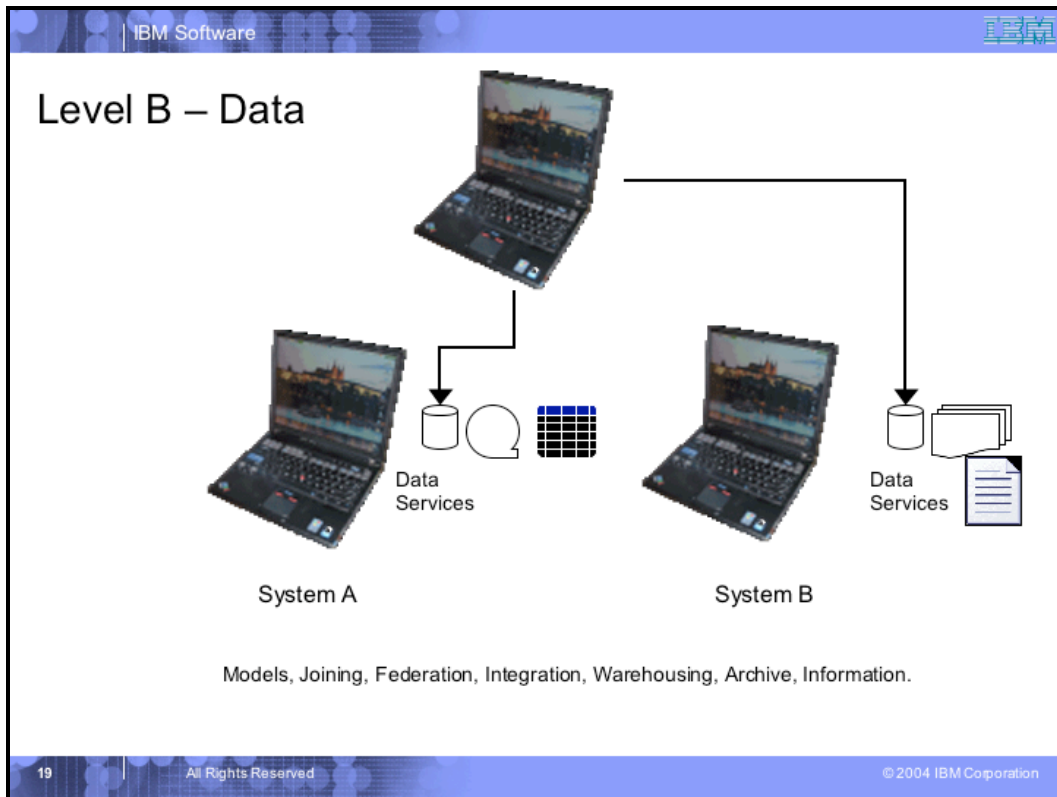
Presentation Services



System B

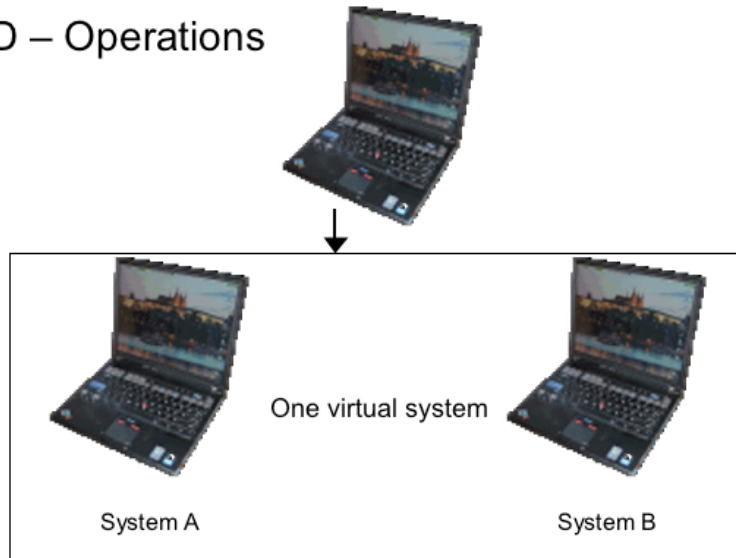
Portals, Cut/Paste, i81n, Visuals, Caching







## Level D – Operations



Monitor, Manage, Trace, Update, Recover, Restart, Configure, Server Consolidation, Virtualization

## Level E – Security

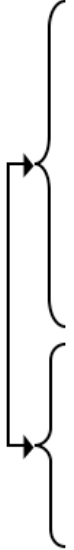
- **Pervasive across all levels of interoperability**
- **Each level specifies security characteristics**
  - i.e. Level 4.1 or 4.2



System N



## Interoperability Feasibility Assessment



Level	Arch 1	Arch 2	Description
1	X	X	Network connectivity: Networked machines; wire/wireless
2			Network protocol: TCP/IP, IPV6
3	X		Static discovery: other systems known statically
4		X	Dynamic discovery: other systems found dynamically
5			Guaranteed delivery:: transfer guaranteed; traceable
6		x	Information: Transmit industry standards data models
7			Enterprise Service: Bus: broker, route, transform, pub/sub, filter.
8	x		Mega System: one to many system access
9	x	x	Lifecycle: Extends beyond runtime to build & manage integration
A		x	Visual: thin, thick, presentation
B			Data: integrator, federation, warehouse
C		X	Service: functional, logic, rules
D			Operations : management, platform, recovery
E		x	Security: multi level, rules

## Interoperability Feasibility Assessment (cont.)

- **Each candidate system to be considered for inclusion in an interoperability transformation must provide a feasibility inventory**
  - Includes people, business and technology items
- **The more that is known about a system's usage and development, the easier the integration estimation**
- **Not all systems will become interoperable...**
  - Cost limitation
  - Skills availability
  - Time



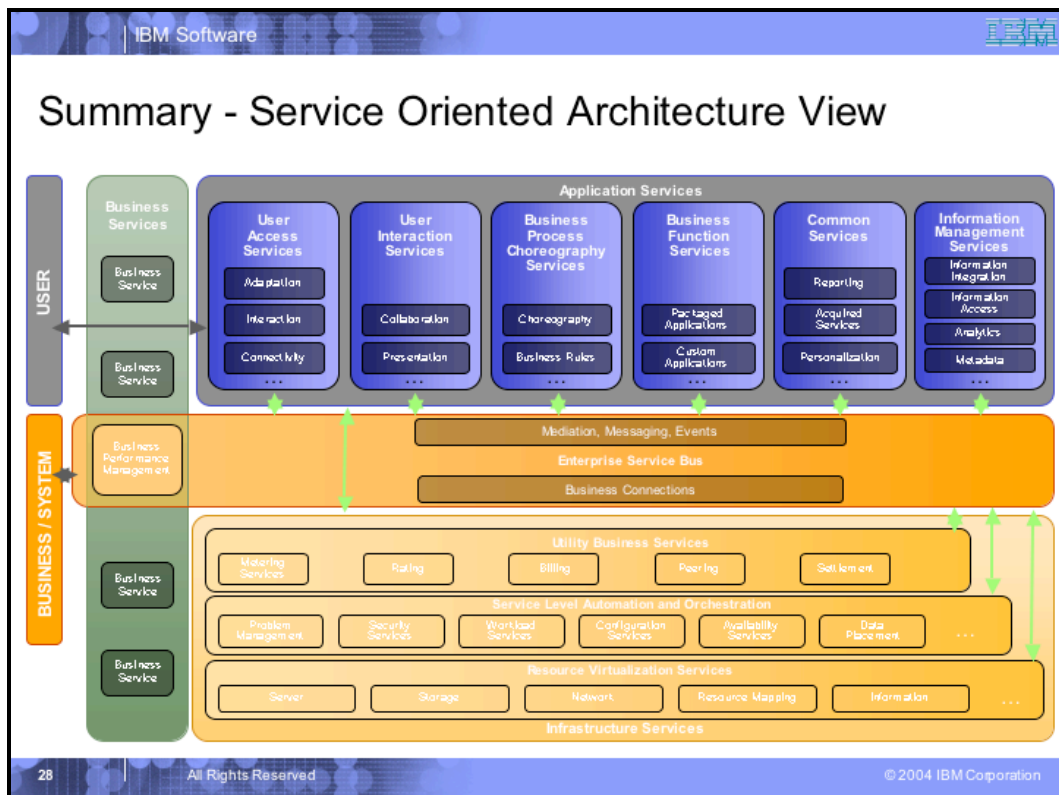
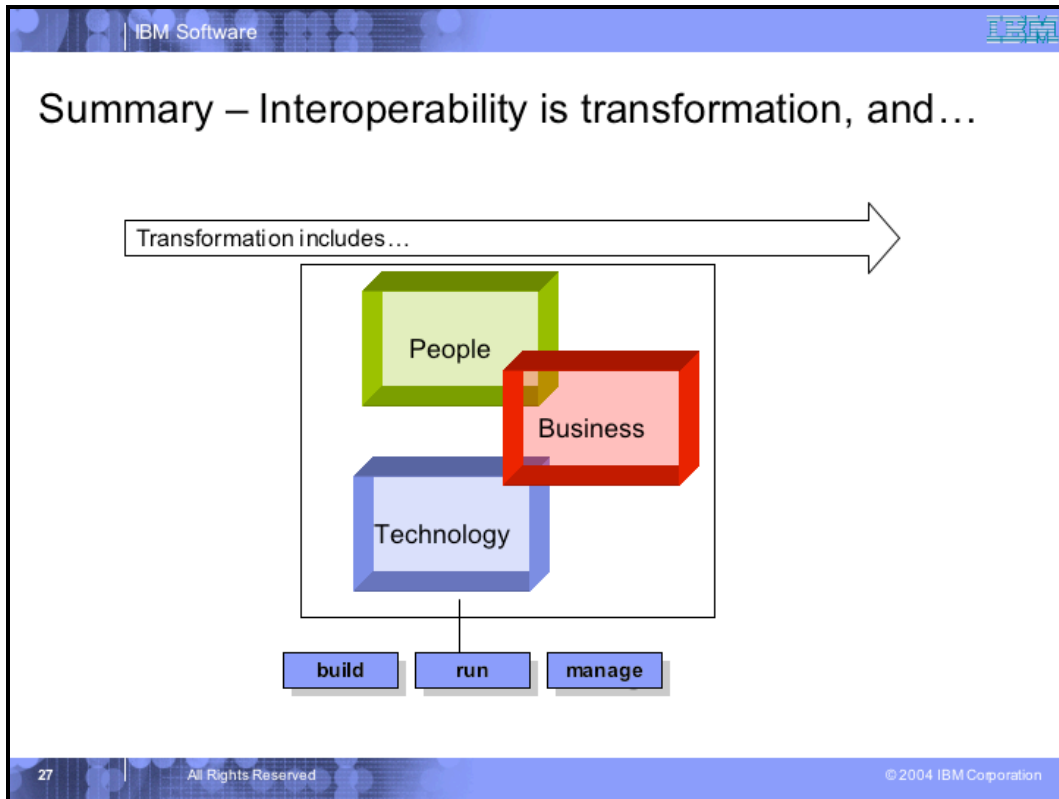
## Interoperability Feasibility Assessment (cont.)

- Open Standards Supported
- External Functional APIs
- External Data SQL
- External Data Models
- Transaction Boundaries
- Error Logging and Handling
- Security Contexts
- Data Throughput
- Caching
- Operating System Dependencies
- Hardware Platform Dependencies
- Network Dependencies
- 3<sup>rd</sup> Party Dependencies
- Tools
- Proprietary Systems

## Interoperability Feasibility Inventory (cont.)

- SME Usage Skills
- SME Development Skills
- Modeling Artifacts
- Design Artifacts
- Development Methods
- Coding Standards
- Build Processes
- Testing Processes
- Deployment Processes
- Performance per invocation
- Configuration management
- Operational Procedures
- Change Management Processes
- Recovery / Restart Process
- Systems Management Processes
- Release Schedule
- Security Clearances









IBM Software

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# *Interoperability Cost Estimation*

*Sixth Annual ONR/CADRC Decision Support Workshop*

September 2004

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## *Network-Centric Defense & Interoperability*

*Family of Systems* defined by platform types in architecture:

- Goal is layered defense against missile attack
- Family already exists: Aegis, Patriot, AWACS, TPS-59...

*Interoperability* is *sharing data to improve performance*:

- often "fire-control quality", low latency, frequent update
- sensor netting, precision cueing and integrated layered defense
- sensor-shooter link to exploit sensor and interceptor range

*Interoperability* can help *avoid serious tactical problems*:

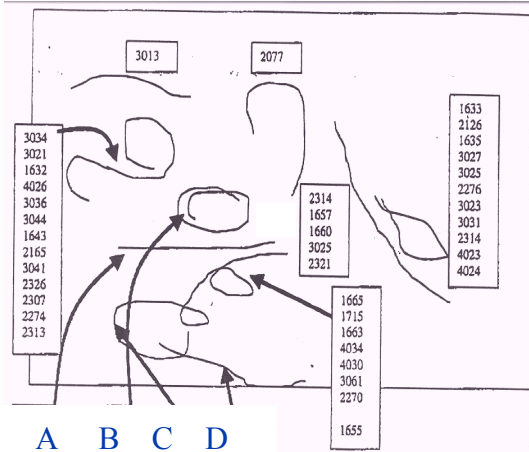
- *duplicate tracks*: ID loss, interceptor wastage. leakage
- *small defended footprint*: many defenders, small keepout range



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## Interoperability Can Avoid This Track Confusion



A	B	C	D
1664	4014	2270	2316
1665	3057	1645	3043
2314	3132	3062	4021
1671	2315	3047	1654
1700	1632		4022
1701	3042		3040
1705	4007		3033
1677	4010		1570
1675	2267		3037
1674	1676		2302
1672	1646		1570
1670	3033		2242
1667	4020		
1706	4012		
1707	2312		
1710	1652		
1711	4013		
1714	1653		
	1722		
	4027		
	1716		
	1721		
	1722		
	3064		
	3066		
	4031		
	1712		
	3031		
	3057		
	1713		

14 minutes  
from a recent  
Link 16 track  
history

The average  
track lifetime is  
2 minutes.

Constant turnover of target designation  
can allow both leakers and fratricide.

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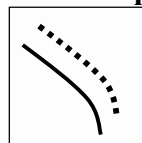
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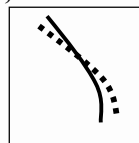
## Key Enabling Concept 1: Gridlock

**Gridlock** means all units know own position, horizon, north:

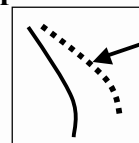
- gridlock enables precise sensor registration
- precise sensor registration enables cueing, avoids duplicates, and allows composite tracks



Sensor 1,  
position error

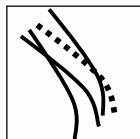


Sensor 2,  
direction error

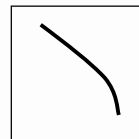


Sensor 3,  
position & direction errors

Ground  
Truth



Without gridlock,  
3 apparent tracks, all wrong



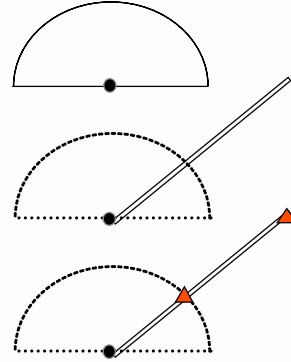
With gridlock, 1 single  
composite correct track

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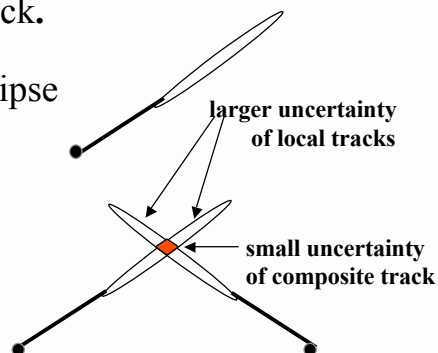


**Key Enabling Concept 2: Cueing**

- Precise cueing tells sensors & weapons where to look and thereby increases range.
- Without cues, sensor energy is spread over entire field of regard.
- Precise cues allow sensor to focus energy and thereby extend range.
- Increased sensor range allows earlier tracks & earlier intercepts.

**Key Enabling Concept 3: Composite Track**

- A composite track is more precise than any single sensor's track.
- Each sensor has an error ellipse of target uncertainty.
- Intersecting ellipses reduce position uncertainty and allow an earlier intercept.
- *Composite tracks are always at least as good as local tracks.*



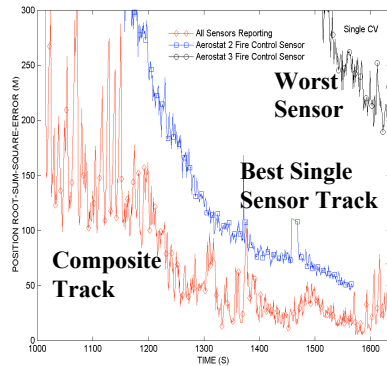


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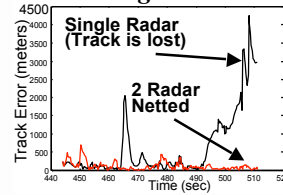


## Interoperability Improves Tracks & Results

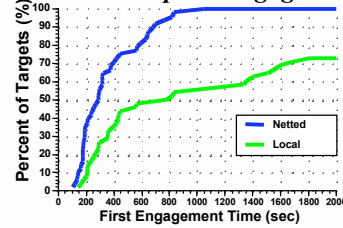
### Composite Tracks Are Always Better Than Individual Tracks



### Composite Tracks Persist When Single Sensors Fail



### Composite Tracks Allow Earlier & More Complete Engagements



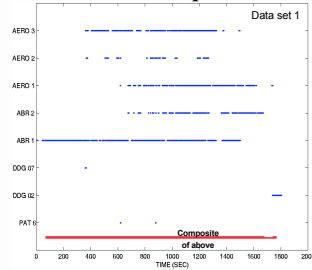
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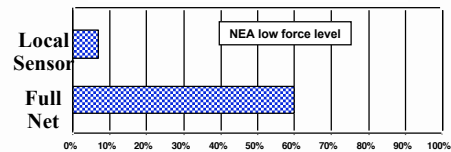


## Composite Tracks Lead To Improved Results

### Continuous Composite Tracks

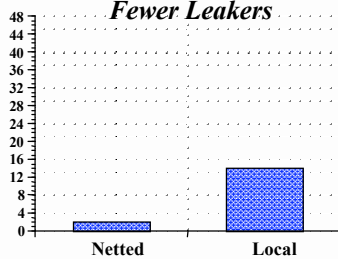


### Earlier First Engagement

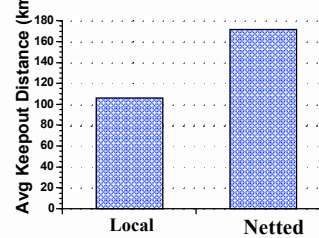


Average % of Cruise Missile TOF Remaining at Time of 1st Intercept

### Fewer Leakers

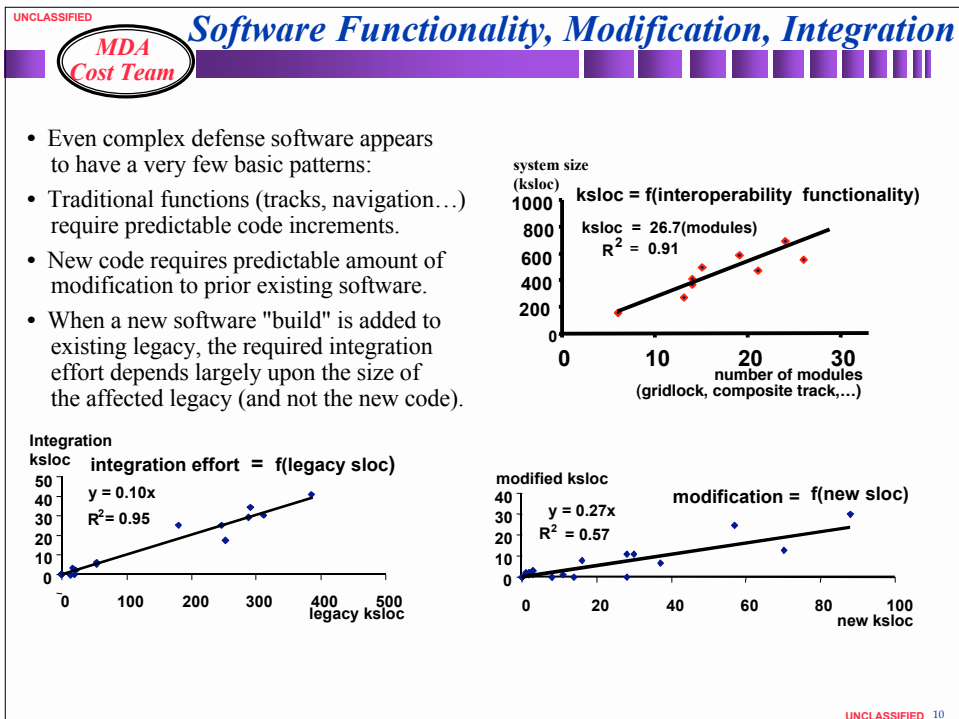
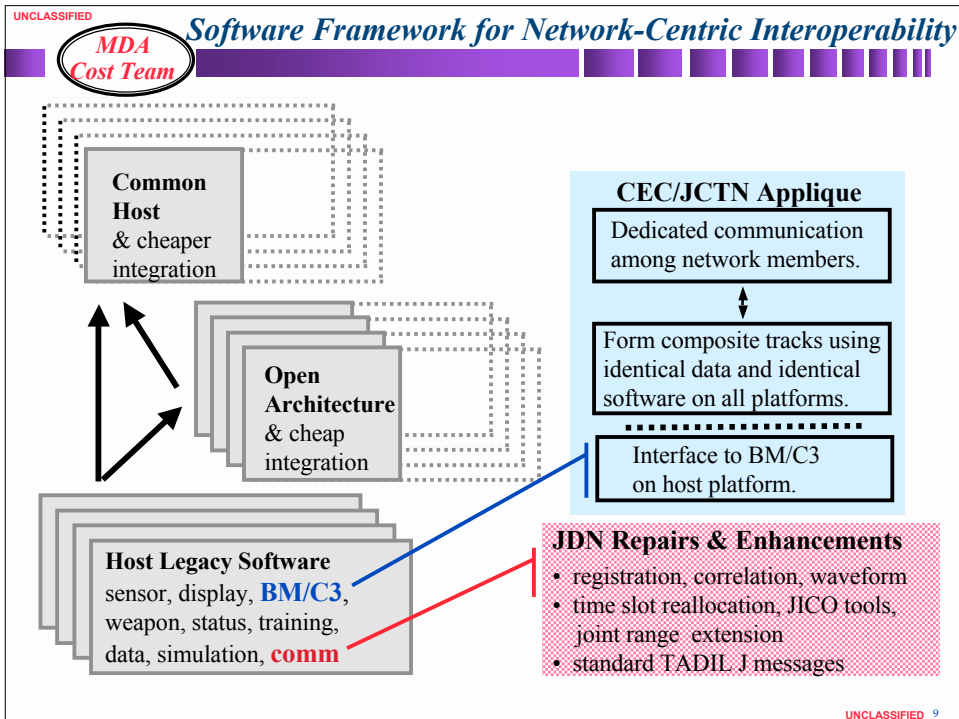


### Bigger Keepout Distance

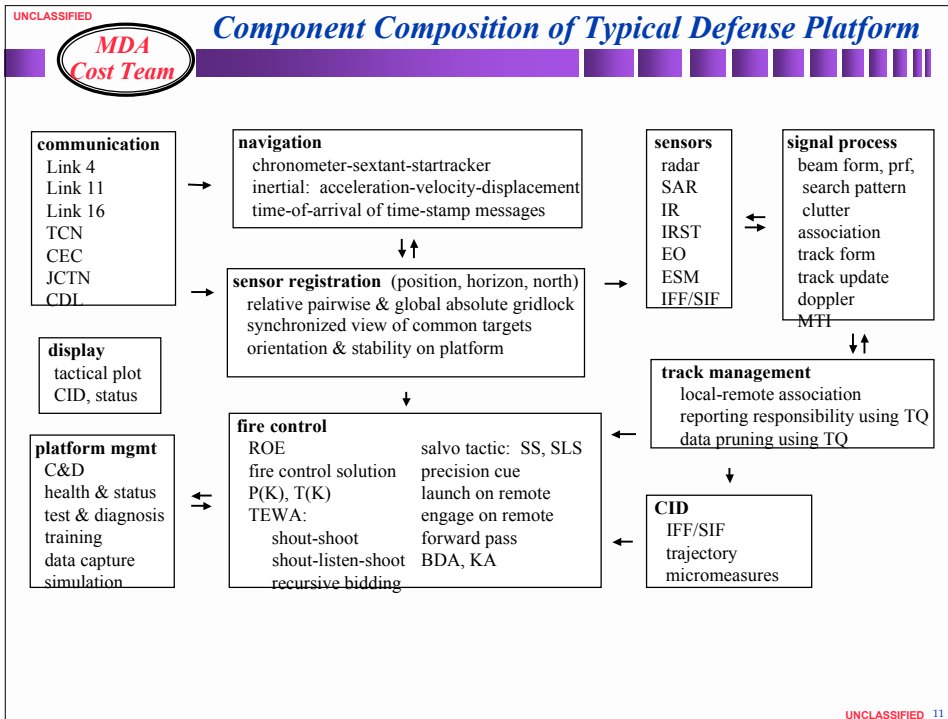


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### Estimates for Functionality-SLOC-Cost Translations

platform elements	ksloc	sensors	cid	fire control
platform mgmt		radar	IFF/SIF	ROE
startup & test	25	beam-forming	trajectories	fire control solution
data capture	25	scan patterns	micromeasures	P(K), T(K)
health & status	25	data reduction		integrated fire control
diagnosis	75	clutter suppression	communication	precision cue
display & control	25	doppler	link 4	launch on remote
dbms & access	75	SAR accrual	link 11	engage on remote
training		send message	link 16	forward pass
operator	75	receive message	TCN	salvo techniques
analyst	75	IR	CEC	shout-shoot
maintenance	75	IRST	JCTN	shout-listen-shoot
		EO	CDL	recursive bidding
		MTI	crypto	
timing		ESM	genser	weapon control
CPU	10	scan patterns	high	launcher mgmt
emission-CPU	20	detect, localize	multilevel	firing
		lookup, classify		telemetry
navigation		sonar	battle management	simulation
celestial	30	passive	interactive display	scenario generation
inertial	30	active	battle plan	platform simulation
TOA	50		threat evaluation	component simulation
		tracker	countermeasure mgmt	s/w assessment
sensor registration		track formation	jamming	postprocessor
relative pairwise	30	association	decoys	
global absolute	30	track update	engagement replay	
PPLI	30	local-remote association		
common target	30	composite tracks		
		reporting responsibility		
		data pruning		

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**TADIL J Costs Depend Strongly Upon Integration Choices**

Services report **widely varying unit costs** to implement a TADIL J message:

- USAF & USA report cost per message of ~ \$1m
- USMC reports cost per message of \$14m
- USN reports that most cost is for host integration

Cost Conjecture: **TADIL J message costs vary widely because of differences in project timing, extent of integration, and size of host legacy.**

**TADIL J Message Costs = Message Design and Coding + Integration with Legacy Software**

Message Design and Coding	Integration Effort as % of Affected Legacy	Integration Extent	Size of Host Legacy SW
= • 2500 sloc @\$200	• 3% if during upgrade	• 400 ksloc comm	• OA shrinks 50%
+ • \$200 ODC/sloc	• 15% all other times	• 400 ksloc C&D	• CHS shrinks
	• 10% observed result	• 400 ksloc display	FOS totals
		• 400 ksloc sensor	

**Sample Message Costs As Driven Largely By Integration Circumstances:**

Low	\$1m	= (2500 sloc)(\$400) + no integration required (or wanted)
Medium	\$3.4m	= (2500 sloc)(\$400) + (3%)(200 ksloc OA comm)(\$400)
Very High	\$20.2m	= (2500 sloc)(\$400) + (3%)(1600 ksloc)(\$400)

**Key Questions:** Does TADIL J message arrival automatically update host data?  
Does new host data automatically generate TADIL J message?

**Integration Driven by Affected Legacy Software**

Software Components			Software Active and Modifiable at Various Levels of Integration			
Size	Name	Function	Display Only	Feed JCTN	Comp Tracks	Full JCTN
450k	SPY	radar		X	X	X
500k	C&D	command		X	X	X
450k	ADS	display	X		X	X
400k	WCS	weapon control				X
350	ORTS	op readiness	X	X	X	X
350k	ACTS	training	X	X	X	X
50k	FCS	fire control	X	X	X	X
900k	ACSIS	data/simulation	X	X	X	X

**Given:** Integration Effort  $\square$  0.10 x Affected Host Legacy Software

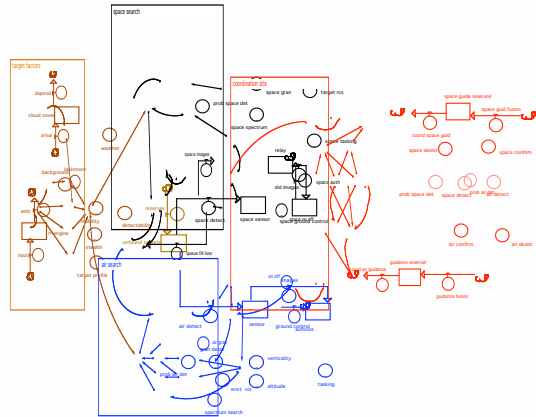
**Then:** Effort for JCTN      64k+OH   128k+OH   192k+OH   256k+OH  
Total (including OH)      ~300k   ~ 350k   ~ 400k   ~ 450k

**Key Point:** Host integration effort steadily increases with higher levels of interoperability, with a minimum effort of at least 0.5 of the maximum integration effort.



## Estimating UML Software From Modeling Diagrams

***UML diagram for BMC3 design for coordinated space-search & air-search for time-sensitive targets***



*resulting UML sloc*

[illegible]

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## Interoperability Efforts Have Required Decades—Not Years

## CEC RDTE

### 1. CEC has a 20-year RDTE span with 12-year installation period

- **PDRR** 14 years (1985-1998)
- **EMD** 10 years (1995-2004)
- **Produce & Install** 12 years (2000-2012)

## JCTN RDTE

System	Count
Sentinel	5
Aegis	5
E-2C	5
TPS-59	6
AWACS	8
CEC/CRE	8
Patriot	8
MEADS	9
JLENS	10

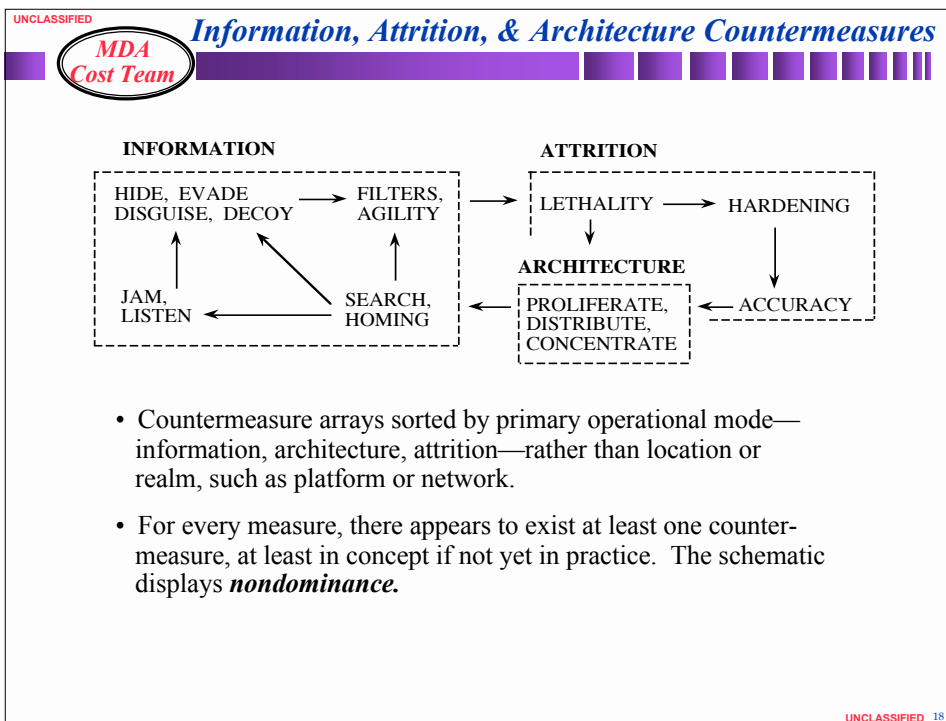
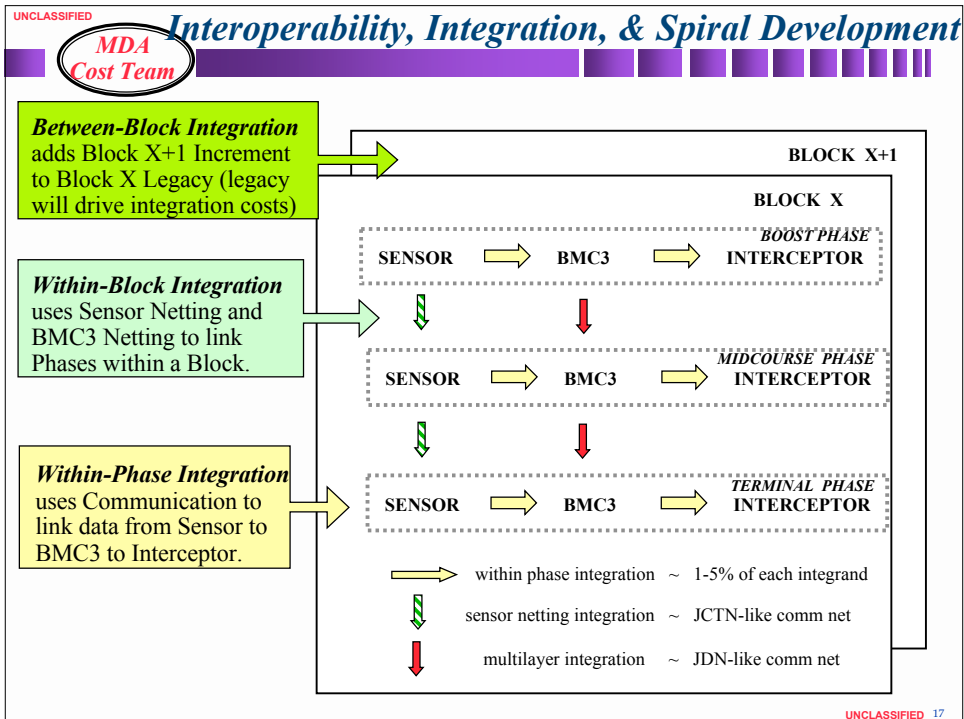
**2. A CEC-like JCTN is estimated to require an 8-year (2005-2012) RDTE effort for design and 3 software builds to achieve 1000 ksloc new code.**

**3. Integration of CEC/JCTN by FOS members is estimated to by them to average 8 years.**

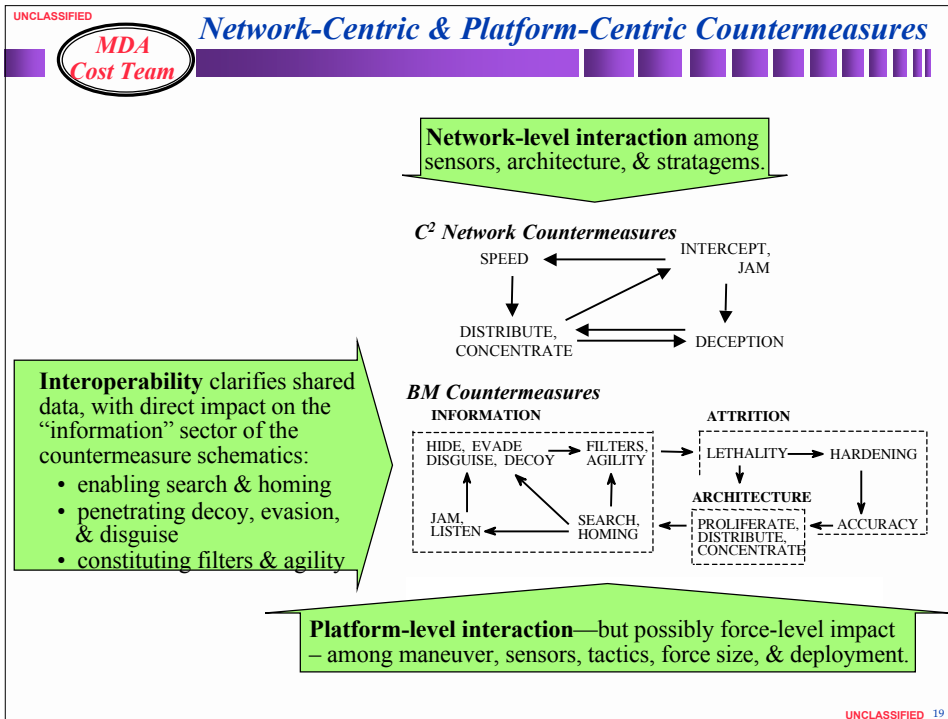
4. **This combination of CEC + JCTN + Integration means that a JCTN-based FOS Interoperability Architecture is possibly achievable by 2020 (not 2010).**
5. **However, one way to achieve a JCTN-based architecture close to 2010 is to have FOS members start preparing *today* to join CEC, and then upgrade to JCTN.**

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## Sanity Checks on Interoperability Cost Estimates

- Estimate to integrate THAAD and CEC/JCTN
 

<b>THAAD Project Office</b>	565 ksloc
<b>MDA Cost Team</b>	540 ksloc
- Estimate to test CEC on AWACS
 

<b>AWACS</b>	\$45 M
<b>MDA Cost Team</b>	\$50 M
- Reconciliation of JCTN estimates of integration costs with both **THAAD** and **Patriot** within \$1M after assumptions made comparable (same software maintenance levels, etc)

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## Network-Centric Interoperability Lessons Learned

- ***Keep a very strong focus on the BASIS of costing***
  - Cost estimation and technical design can greatly help each other
  - Understanding & estimating cost drivers is difficult but essential
- ***Good approximation » detailed error***
  - Avoid detailed cost accounting schemes
  - Focus on **approximating** the main drivers
- ***Excursions, sanity checks, sensitivity***
  - Uncertainty makes a family of estimates essential
  - “Approximate Cost Previews”
  - Examine neighborhoods and boundaries
- ***Full life-cycle estimates to find trades, avoid surprise***
  - Example: reliability trades RDTE vs Production vs O&S
  - Example: Stopping at FUE can hide Production and O&S growth
- ***Failure analysis (beyond risk, sanity, sensitivity)***
  - What might failures look like?
  - Search for cost precipices & precursors of failure

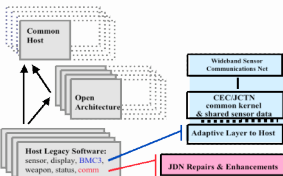
## Interoperability Cost Estimation Backup

- Software As A Basis Of Estimation
- How CEC Can Evolve To JCTN
- AEGIS Integration Details
- Open Architecture & Common Host
- Interoperability Cost-Benefit With Link 16 & CEC and Common Host & Legacy Software
- Interoperability Cost Estimation Experience
- Estimated Costs of Field Testing Interoperability



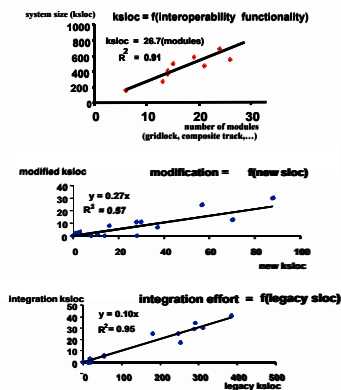
## Macro &amp; Micro Software Enabling Patterns

## Primary Macro Software Pattern



- Each platform is a software ensemble.
- Legacy platform software can be replaced by Open Architecture, Common Host, or an OA-CH sequence.
- Replacing legacy software with Open Architecture can produce new platform software on each platform whose size is about 0.5 of the legacy sloc it replaces.
- Replacing legacy software with Common Host can produce a single new platform software for all platforms whose size is about 0.5 of a single platform's legacy sloc.
- Current strategies to improve platform interoperability include improving communications, augmenting battle manager, and overhauling entire legacy software.
- Improving communication means Link 16 Repairs & Enhancements (TSR, JRE, JICO, Standard Messages).
- Battle Manager augmentation often means a CEC/JCTN common kernel processing shared sensor data from a wideband sensor communications net.
- Common Host & Open Architecture lower Integration cost of JDN & CEC/JCTN by reducing platform sloc size.

## Primary Micro Software Patterns

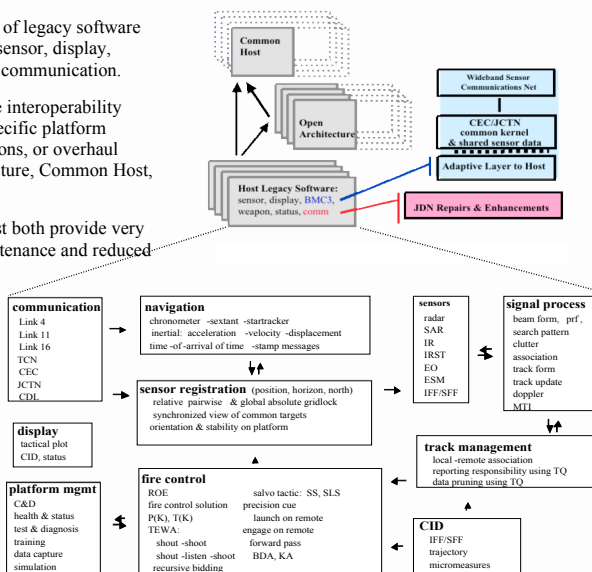


- Platform functions & capabilities usually require predictable amounts of software & integration.
- Modification of existing software by new code is on average 4 lines new □ 1 line modified.
- Integration effort is driven by the size of affected legacy, generally equivalent to 10% of legacy.

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## Platform Functionality In A Network Context

- Each platform contains an ensemble of legacy software that operates its primary activities: sensor, display, BMC3, weapon, status, navigation, communication.
- Two basic strategies exist to improve interoperability among platforms: either improve specific platform modules like BMC3 or communications, or overhaul legacy software using Open Architecture, Common Host, or do both.
- Open Architecture and Common Host both provide very compact software, with reduced maintenance and reduced integration for module improvement.
- Each platform element contains multiple elements, which may be ensembles like Link 4, Link 11, Link 16...or alternatives like chronometer, INS, TOA navigation.
- Platform elements include provision for successive enhancement:  
*shout-shoot, shout-listen-shoot, bid precision cue, launch on remote, EOR*

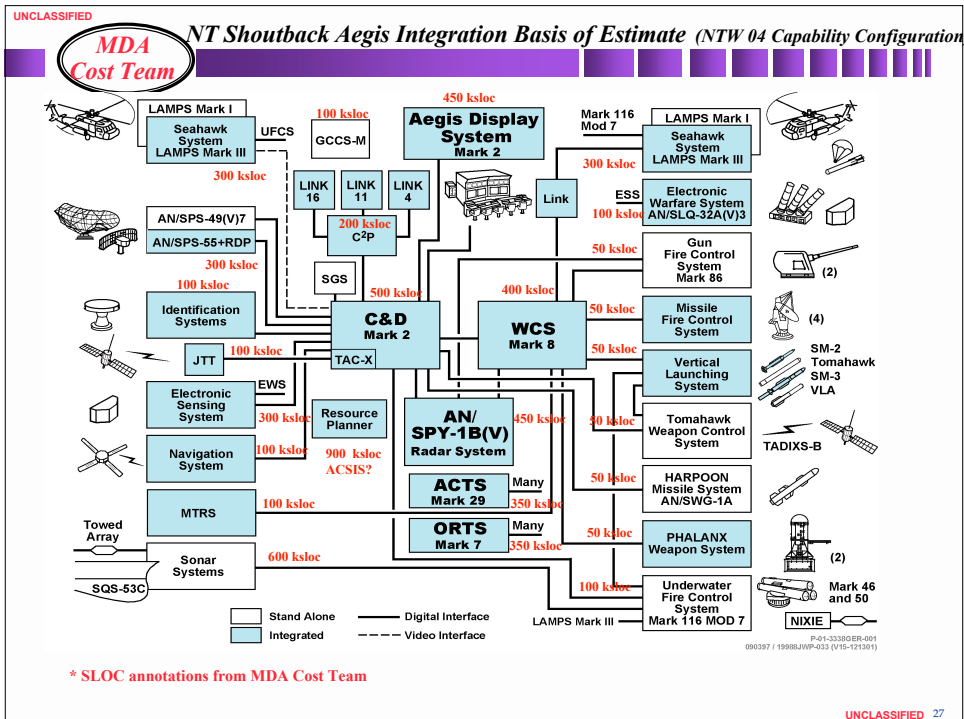


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### AEGIS Shoutback Integration Potential Cascades

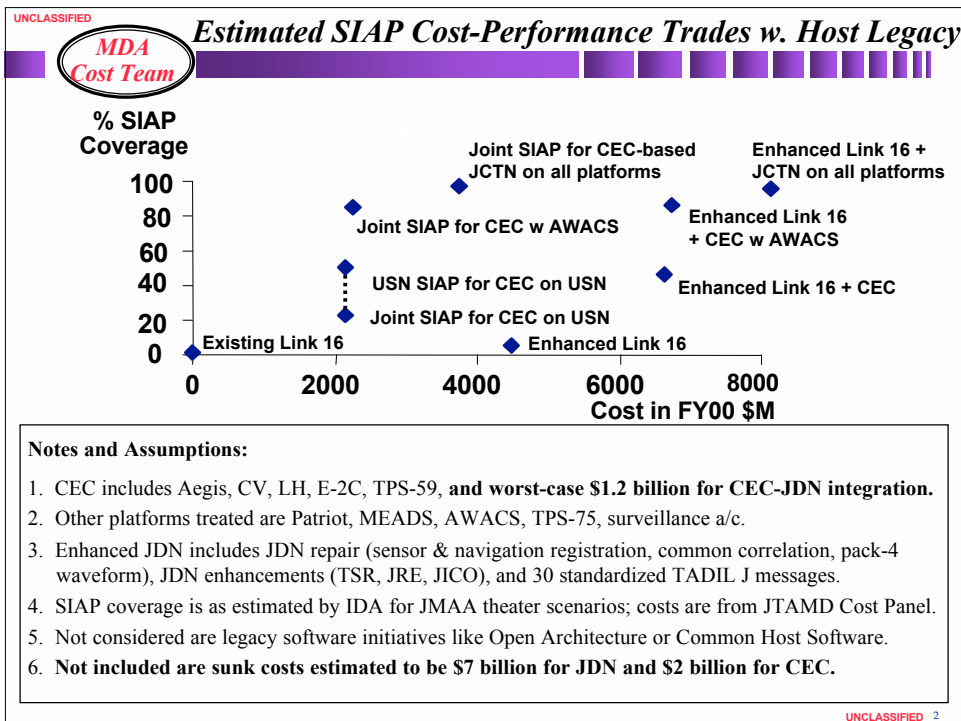
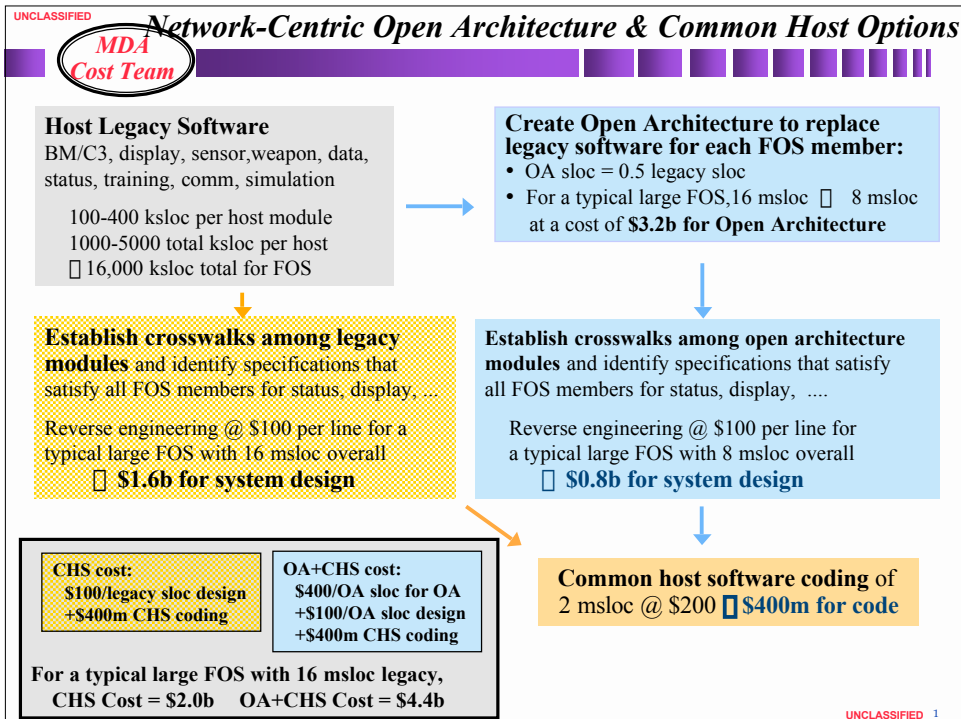
System	ksloc
C&D	500
ACDS	450
SPY	450
WCS	400
ORTS	350
ACTS	350
FCS	50
ACSIS?	900
<b>aegis system subtotal</b>	<b>3450</b>
LAMPS	300
AN/SPS-55	300
ID SYSTEMS	100
JTT	100
ELEC SENS SYS	300
NAV SYS	100
MTRS	100
C2P	200
EW SYSTEM	100
VLS	50
PHALANX	50
SSDS	100
<b>integrated subtotal</b>	<b>1800</b>
SONAR	600
GCCS	100
GUN FIRE CONTR	50
TOMAHAWK	50
HARPOON	50
UW FCS	100
<b>stand-alone subtotal</b>	<b>950</b>

**Shoutback Entry at MTRS Into Aegis Platform Ensemble of Software.**

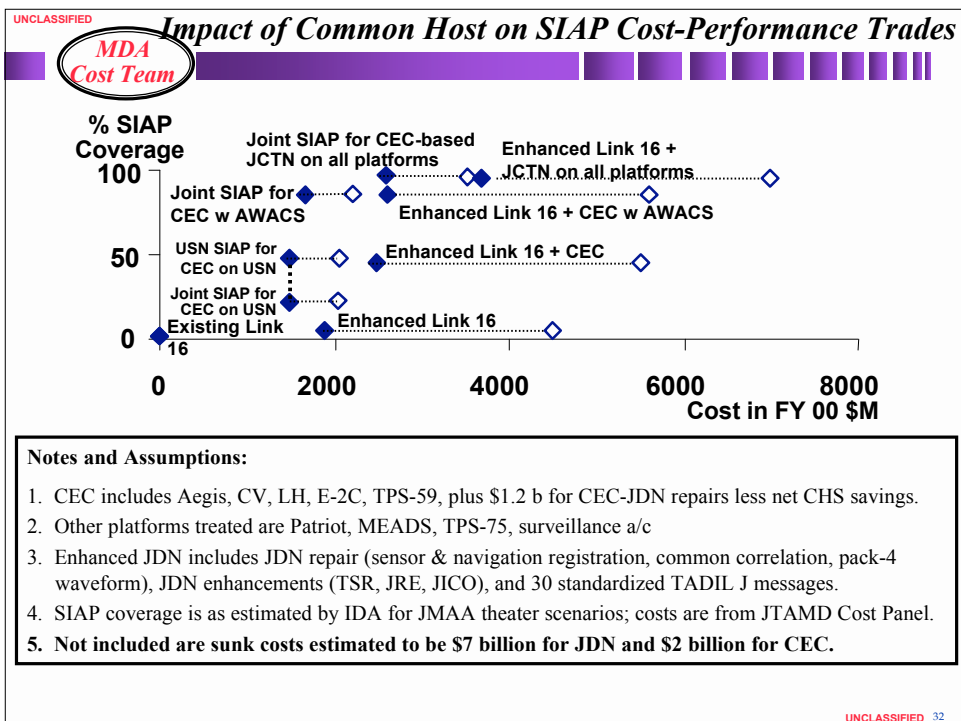
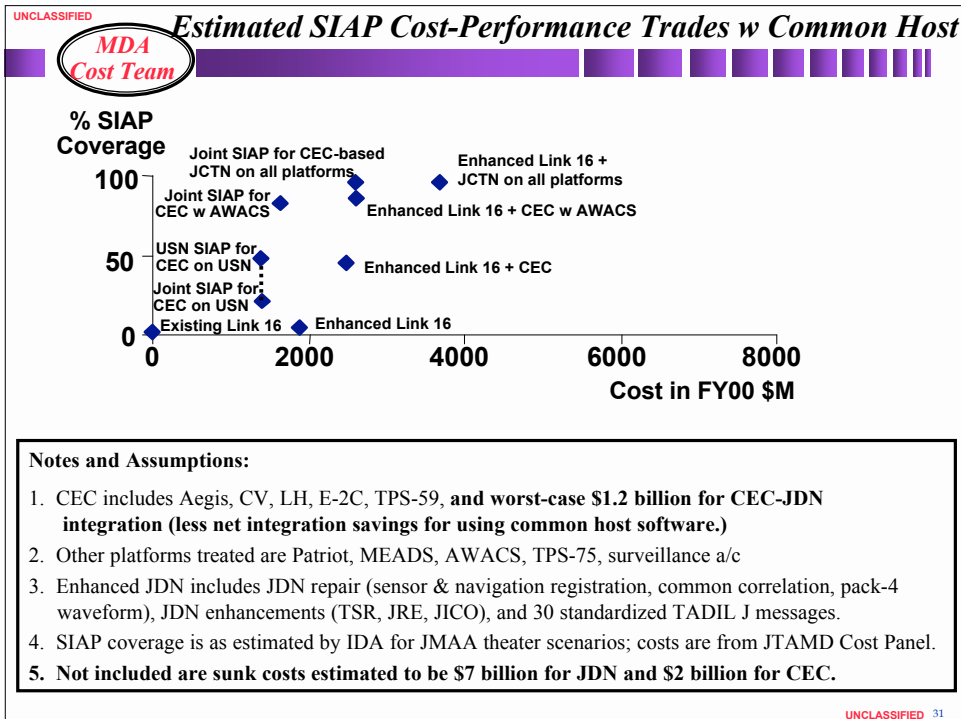
**Integration of Shoutback data (and the J 10.2 message) into primary the Aegis ensemble, integrated elements (e.g. SSDS), but probably not into stand-alone elements (such as sonar).**

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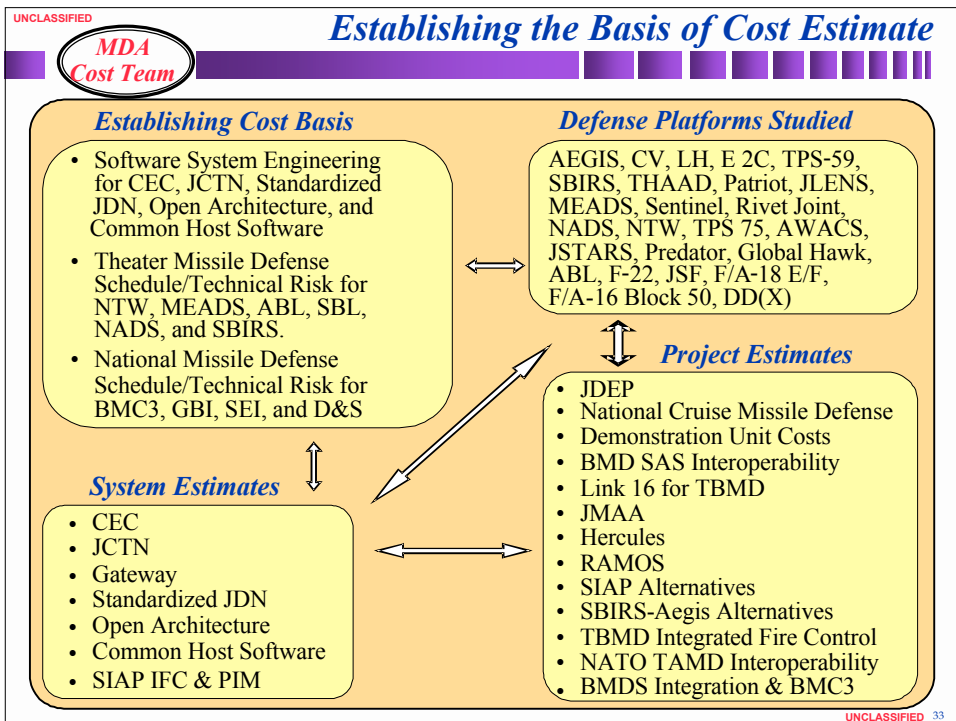












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## Defense Platform Cost Estimates Without CARD 1996-2003

<i>CEC</i>	<i>Created 20-year RDTE detailed technical profile to relate specific functions to software size.</i>
<i>JCTN</i>	<i>Created 10-year RDTE detailed technical profile as a direct extension of CEC, relating expanded functionality to successive software builds and sloe growth.</i>
<i>JTAMD Master Plan</i>	<i>Estimated costs of a baseline JTAMD architecture defined by the O&amp;A WIPT, treated as a JCTN baseline excursion.</i>
<i>Minimum Mix</i>	<i>Revisited CEC/JCTN concepts including participation, integration levels, population sizing for a top-down, bottom-up JCTN cost scrub.</i>
<i>Gateway</i>	<i>Identified software functionalities required to implement JCTN/JDN Gateway.</i>
<i>JTAMD Demonstrations</i>	<i>Used MDAP CEC/JCTN integration approaches and estimates to develop estimated unit costs of missile defense field tests and demonstrations.</i>
<i>IPP Increments 4-7</i>	<i>Identified the selected subset of JCTN functionality that corresponded to the IPP framework. Identified \$5B overlooked costs due to FUE limited horizon.</i>
<i>National CMD</i>	<i>Created architecture &amp; conops of layered multiple corridors defended by Aegis, Patriot, AWACS+CAP... Estimated patrol O&amp;S cost = \$5M/week/layer/corridor</i>
<i>Common Host Initiative</i>	<i>Devised software strategies to derive Open Architecture and Common Host coordinated software replacements for family of system legacy ensembles.</i>
<i>BMDSAS Capital Budget</i>	<i>Estimated the interoperability integration costs of a long-term capital-budgeting approach to upgrading defense platform ensembles</i>
<i>JMAA</i>	<i>Defined solution techniques for JDN repairs, enhancements, and standardized TADIL J messages, then estimated the costs to implement and integrate the implemented solutions into FOS platforms.</i>
<i>RAMOS</i>	<i>Defined Engineering Integration Team roles, missions, &amp; structure, and likely Soviet cost drivers, estimated major RAMOS architectural and O&amp;S alternatives.</i>
<i>SIAP Block 1, PIM/PSM</i>	<i>Developed a general platform model that describes how desired platform functionality and interoperability drives software size.</i>
<i>NATO Feasibility</i>	<i>Reviewed draft TAMD Architecture Feasibility Studies and identified missing essential elements that create or prevent system feasibility. The revised studies may have some value.</i>
<i>BMDS Block 06, KE Boost</i>	<i>Developed a general platform model that describes how desired platform functionality and interoperability drives software size.</i>

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**Estimated Costs of Testing Interoperability**

Performance	Venue	Expected Role of Estimate	Estimated Number of Trials, Units

**Why the proliferation of performance trials:**

**(2 sensors)(2 networks)(2 weapons)(4 target types) = 32 combinations**

- + variations in force size and geography
- + variations in firing doctrine, etc
- + variations in threat size and capability
- + repetition to gain confidence in results

**Some ways to mitigate performance estimation cost:**

- augment existing exercises vs JTAMD-dedicated trials
- substitute JDEP and simulation for field trials
- coordinated program of field test, JDEP, and simulation
- ~~spiral development to winnow choices & also choose more wisely~~



# Information Interoperability Engineering

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## Introduction

The concept of interoperability has a broader scope than merely data exchanges. It may describe the ability to request and receive services between various systems and use their functionality. In this more general sense interoperability implies the existence of features such as: exchange of messages and requests, mutual use of system components' functionality, at least client-server abilities, distribution, operate multiple systems as a single unit, communication despite incompatibilities, extensibility and evolution.

The Multilateral Interoperability Programme (MIP) is one major international effort to attain interoperability among NATO information systems. MIP gets a lot of visibility because its interoperability standard is actually incorporated in operational systems and tested "in the field". The MIP interoperability approach provides a promising solution, especially with respect with its exchange data model, C2IEDM (C2 Information Exchange Data Model).

C2IEDM represents a reference, or a central data model as the of an interoperability solution. By providing a single data model, this is in fact an ideal technical solution. It has also the indisputable advantage of being a widely accepted solution. Nevertheless, it still requires considerable implementation and maintenance effort. It can be argued that system-wide interoperability can be improved considerably by harmonizing instead of centralizing around a single data model, all major information modeling efforts within DoD, including C2IEDM.

Interoperability contexts can be defined for different interoperability solutions. Interoperability domains can be defined by identifying the information services relevant to a given context. To do this, it is necessary to define what an interoperability solution is, and classify all these solutions. One can then associate interoperability domains with interoperability solutions. This approach is more flexible than imposing a unique reference data model for all interoperability contexts.

Interoperability cannot be efficiently addressed as a whole, and as a consequence the interoperability solutions are not unique. There is currently a common and significant trend towards interoperability approaches that recognize this important aspect. Interoperability models are proposed using quite similar concepts such as interoperability layers, degrees of interoperability, or interoperability levels.



We argue there is no universal, system-wide interoperability solution; any solution covers only a given portion of the full interoperability problem space. Although theoretical completeness can still be a strong criterion of adoption, the validity of any solutions is always expressed by the degree it satisfies practical requirements of specific and real situations.

We will briefly describe some relevant interoperability models, and we propose a context-based model for NCES, arguing that even if the current approaches are necessary, they are not sufficient in the long run.

From a theoretical point of view, there are at least three different levels of abstraction for data modeling: syntax, semantics and pragmatics or operations. At each level data models can be constructed and expressed by using specific languages and tools.

We argue that for an interoperability model to succeed two conditions are necessary: it has to address each interoperability problem in its own interoperability context, and all levels of data abstractions have to be explicitly addressed by the model.

## **What is Information Interoperability?**

In essence, information interoperability refers to the unambiguous information exchange between sources that are willing to share their information. In other words, data that crosses different systems has to be correctly interpreted. In practice, there are certain obstacles that usually prevent the realization of a simple interoperability solution. The analysis of the usage scenarios helps to understand the nature of these obstacles in a given situation.

One of the most common problems that have to be overcome by interoperability is the *information infrastructure heterogeneity*. In a heterogeneous system environment, it is often possible that data be represented using various formalisms and methods such as relational databases, XML documents, proprietary databases, object oriented databases, file records, etc. Some interoperability solutions can be provided by different middleware approaches.

It is also not unusual that some repositories have almost the same content, using the same formalism, but being *differently structured*. The interoperability approach may provide solutions to this problem by matching semantically compatible elements and by mediating between different representations, in general, mapping across representation systems. Mediate between different representations essentially means to reconcile different representations of the same concept.

Most data models were invented for operations that didn't involve data interoperability, such as accessing and retrieving from known data sources. Interoperability issues appear when data sources are not necessarily known, and when the format and content of data are different or even unknown at the design time. We need a data model that specifically addresses the interoperability between different data models at more abstract levels. Without it any attempts to solve interoperability problems risk to be inconsistent, partial, and difficult to generalize for new



data models. We need a model that can be applied to all data operations that take place in the systems: searching, retrieving, accessing, interpreting, aggregating, fusing, mapping, etc.

## **Engineering Information Interoperability**

The information interoperability architectures are inherently biased towards the architectural concepts used for the systems they are part of. Traditionally, the interoperability design made use or adapted concepts from the relational databases and client server architectures for distributed systems. Recently, the main architectural themes are the Enterprise Application Integration (EAI), Service Oriented Architectures (SOA), Web Services, and in perspective the Semantic Web. Concepts and patterns from these different architectures are to be found in today's interoperability design.

Important to note is that choosing the right interoperability architecture is not always only a technology option. Different architectures can actually coexist or can be used in layered approaches, mainly due to practical engineering reasons such as effectiveness, robustness, or cost, rather than architectural "purity".

Some solutions, such as for instance data standardization might work well for small, simple enterprises. For larger enterprises, it seems more appropriate to have many data models, each covering a given functional domain, so that the systems can adopt data definitions from the appropriate model. As a result, the interoperability focus moves towards the communication between systems, across the boundaries of different models.

Some interoperability solutions will be enumerated in the following. This does not represent a systematic approach; it is rather an attempt to place the current efforts into a more general perspective.

***Unique data model or data standardization.*** A new, unique data model is defined for different information systems with different data models. This is one of the simplest ways of achieving information interoperability. It has its advantages, such as being very easy to use by the end users, as it appears to be one single information system. In turn, it is difficult to define, because it needs human understanding to define an integrated data model. Another disadvantage is the loss of local autonomy, with all its consequences – difficult to maintain, cannot adapt easily to specific local requirements, etc. It is also a static solution in the sense that it cannot evolve automatically – there is always a need for human intervention to define new data model elements.

***Database replication mechanisms.*** Replication is the process of copying and maintaining database objects in multiple databases. Basic replication is useful for information distribution. Using replication critical information is always available, relatively current, and consistent at all targets. Although it can be generalized, this approach is in its present form limited to relational database environments, where it has been first defined and used. An example of this approach is offered by the MIP replication mechanism – ARM.



**Federated Databases.** This refers to a set of individual databases which are managed coherently. Each database contains a logically connected group of objects. Objects can hold references to each other, allowing navigation, including from one database to another.

Exchange Model		Transformation Model		Data Model		Description - Example
P2P n-m	Mediator 1-n	Static	Dynamic	Central	Semantic	
x		x				Static simple transformations between any pairs of sources with any data models.
x		x		x		Static simple transformations between any pairs of sources and a central data model.
x		x		x	x	Static simple transformations between any pairs of sources and a central semantic data model.
x		x			x	
x			x	x		
	x	x				Static simple transformations between any sources and the mediator - <a href="#">NCPP now</a>
	x	x		x		Static simple transformations between any sources and a central model <a href="#">NCPP with C2IEDM</a>
	x	x		x	x	Semantic hub – a central static semantic model
	x		x			Dynamic simple transformations between each pair of sources
	x		x	x		Dynamic simple transformations between any sources and a central model
	x		x		x	Dynamic semantic transformations between any pairs of sources
	x		x	x	x	Semantic hub – a central dynamic semantic model

**Table 1 Interoperability Strategies**

A central administration provides the reconciliation between differences. The source systems provide the physical data and a middleware layer translates the requests. This approach requires that each database system can execute these requests.

**Static Data Transformations.** This approach assumes the existence of pre-defined data translations between each pair of communicating systems, without any specification of their underlying data model. This represents a procedural approach in the sense that it defines how to process data instead of describing the data itself. It is also static, because it is defined at the design time and cannot be changed dynamically at the execution time. The semantics of each data model has to be fully understood only by the developers, and the translations support only the information transfer anticipated during the development. This architecture cannot provide any system functionality that can ensure the dynamic generation of translations at run-time. The development and maintenance of such translations require considerable effort, particularly with the increase of the number of communicating systems.

Nevertheless, this approach continues to be very popular, due mainly to the popularity of textual languages such as eXtensible Stylesheet Language Transformation (XSLT). The same principles



can be applied to other data structures, such as EDI messages, or to disparate database tables using SQL, although the popularity of the method is due by far to the growing number of XML structures in place today.

***Dynamic Data Transformations.*** This more flexible procedural scheme assumes that the translations are automatically generated, at run time, from descriptions of the data used by the communicating pair. These descriptions need to be expressed in a formal language, in the sense that this language has to be machine understandable, at run time. It is also necessary that the descriptions be based on a common understanding of the meaning of the data elements. This common meaning has also to be expressed in a machine understandable manner, so that the mediator can identify and correlate related elements from different data models.

***Data Mediation.*** This approach uses a mediator metaphor for interoperability. The data mediator essentially translates data between two systems with different data models. The mediator dynamically generates data translations according to deployed transformation logic.

There is no assumption on the static or dynamic nature of the data translation itself. For instance, the translations can be achieved by using static data transformations stored in special repositories, such as metadata repositories. This approach may still have all the drawbacks of static data transformations, but offers the advantage of reducing the number of peer-to-peer connections.

***Central Information Model.*** The information model is central in the sense it represents a neutral and unifying view of a group of data models. Neutral means that it doesn't serve any particular domain needs, and it is unifying in the sense that it serves some common purposes of the group. Each of the resources can be mapped to the central model.

The basic architectural concepts of this approach are similar with those of the hub-and-spoke architecture for asynchronous message buses. The idea of a hub-and-spoke is that instead of sending messages between each pair of sending and receiving applications, the source can send a message on the bus, while the potential target applications listen for their messages. For information interoperability, the hub can be represented by an agreed upon central or reference data format, with the spokes represented by any number of other formats. XML is currently the most largely known example of a format for a data hub. Interoperability technologies can import data from most common formats and convert it to the hub format. The hub metaphor is used by many system designers. One of the examples is the MIP C2IEDM which is also known as the General Hub (GH).

***Semantic Information Model.***

This model addresses the most challenging incompatibility problems, those that arise from semantic differences in the structure or schemas of data. While a common data format may never be achieved, this approach has the goal to establish a common understanding. Semantics may save time by ideally capturing the meaning of data once. Another important benefit of using semantic descriptions is that large numbers of data sources can turn into one coherent body of information. This can then provide a common understanding, keeps data consistent and well defined. While informal data semantics has always existed, a more formal semantics brings in the advantage of being equally "understood" by machines.



This information model may be based on any traditional data model or object model but it could also be centered on ontologies, a modeling technique developed for expressing semantic relationships between the elements of a data model. An ontological information model is potentially richer than a traditional data model, including more levels of generalization, business rules, etc. Its generality allows the information model to serve as an authoritative reference for multiple data sources, regardless of format or technology.

In conclusion, one might state that any of the interoperability techniques offers only a partial solution. The whole solution could be for instance, data standardization up to the point when it doesn't become impossible to manage, complemented with data mediation for individual systems that need to maintain their data independence but need to cooperate. Any of the partial solutions helps in certain ways, and it is the architect's and designer's job to determine the right mix.

## **NATO C3 Series of Interoperability Models**

The NATO C3 Technical Architecture [NATOTechArch] uses a series of interoperability models, covering interoperability problems ranging from unstructured data exchange to seamless sharing of information. The interoperability models are part of the NATO C3 System Architecture Framework (NAF) which is mandatory for the NATO systems and recommended to be used by nations for the purpose of achieving interoperability.

NATO uses two types of data models: the NATO Corporate Data Model, and the NATO Directory Data Model. The basic principle for achieving interoperability is to separate data from applications and applications from the computing platforms.

The NATO Corporate Data Model has been developed by The NATO Data Administration Group (NDAG), a multi-national working group. The goal of this model is to provide a source for Standard Data Elements (SDE). The use of SDEs enhances interoperability among NATO C3 systems. A Reference Model contains the semantic descriptions of the SDEs, their interrelationships and information about data structures (ex: maximum field length, data types, etc.). Several project-centric View Models represent data views encapsulating specific examples of the generic SDEs as well as project specific data elements that cannot be found in the Reference Model. The model contains also the semantics and structure of the metadata.

The NATO Directory Data Model has been adopted by the NATO Directory Services Working Group (DSWG). It is intended to support interoperable electronic directory services across NATO. The NATO Directory Data Model is expected to be soon included in the NATO Corporate Data Model. The purpose of this model is to maintain the NATO Directory Schema that covers the directory data types, object classes, matching rules, name forms and structure rules that are necessary to specify the information stored in the Allied Directory System.

The main interoperability concepts that guide the NATO data models include the architectural configurations and their interoperability profiles (NATO-to-NATO requirements), and the Information Exchange Gateways (IEG) (NATO-to-nation requirements).



Recognizing that the interoperability problems cannot effectively be addressed as a whole, NATO emphasizes the need to refine interoperability approaches by introducing the concept of degrees of interoperability. The degrees help to categorize how operational effectiveness can be enhanced by structuring and automating the exchange and interpretation of data. The degrees were further refined into sub-degrees identifying specific interoperability services.

## **MIP – Standard Data**

NATO's Multilateral Interoperability Program (MIP) has the goal *“to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to the lowest appropriate level, in order to support multinational, combined and joint operations and the advancement of digitization in the international arena, including NATO”*.

The main idea behind the MIP data interoperability solution is to *standardize* the specification of the inter-system information exchange requirements. The participant systems agree on the meaning of the exchanged information, with no mandated impact on their local national systems. The MIP concept of interoperability is based on the exchange of *standardised* data elements that use agreed and common data identifiers. The approach is based on using a common data interchange model, namely the Command and Control Information Exchange Data Model (C2IEDM). The role of C2IEDM is to support unambiguous information exchange, or data interoperability, among MIP enabled national C2IS systems.

In the NATO C3 perspective, the MIP solution aims at achieving interoperability degree 2.h (Structured Data Exchange/Data Object Exchange) for its human-interpretable information exchange mechanism and degree 4.2 (Seamless sharing of information/common information exchange) for its systems-interpretable information exchange mechanism.

The C2IEDM in itself cannot express all the constraints that prevent its wrongful utilization. Thus the process is completed by adding business rules and constraints expressed informally in natural language in the documentation that accompanies the formal data model. The resulting MIP data model includes the formal model and accompanying documentation in natural language, so that it can be used to implement in a consistent manner a particular solution based on this model.

C2IEDM comprises data elements describing a fairly large common vocabulary consisting of 176 information categories that include 1500 content elements. In general, C2IEDM describes all elements of interest on a battlefield, such as organizations, persons, equipment, facilities, geographic features, weather phenomena, military control measures, etc. This is also known as the Generic Hub. In addition to this, special functional areas are defined, extending the Generic Hub under national responsibility to respond to the national concerns needs of exchanging information.

It is currently used as the core data model for various C4I systems, and as a reference model for various simulation systems. It also could be used by other information exchange mechanisms lacking a unified information structure, such as message formats.

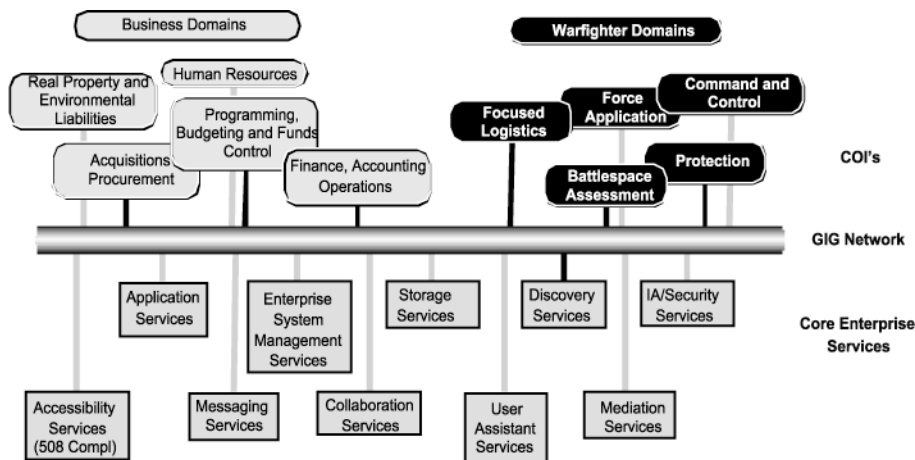


The procedures and documentation required to implement the current version of the MIP interoperability solution, the MIP Baseline 2, includes the MIP Common Interface (MCI) which specifies how an interface to the core data model and ARM needs to be constructed.

The MIP Baseline specifications are not currently based on commercial standards. Nevertheless, there are plans for an XML interface.

## NCES – Standard Metadata

Data interoperability is at the core of the DoD Net-Centric Data Strategy [DoDCIO]. The NCES (Net-Centric Enterprise System) will provide data tagging, searching, and retrieving. The focus is on establishing metadata standards. This approach allows for standardizing the *interpretation* of the data instead of the data itself, as it was the case with previous DoD approaches to data interoperability. The efforts go to establish a standard description in the form of standardized metadata.



**Figure 1. The NCES Architecture**

NCES is materialized by a set of Core Enterprise Services and Community of Interest (COI) capabilities (Fig. 6). The services provide the basic ability to search the enterprise for desired information and then establish a connection producer-consumer. Capabilities are organized around communities of interest such as C2, Intelligence, Logistics, etc.

COIs are established based on data organization and maintenance, and they are responsible for the data. The COIs are supposed to coordinate and align along some guiding principles, without any central node. Registries, catalogs, and shared spaces provide mechanisms to store data and metadata. Metadata describes data assets and the use of registries, catalogs, and shared spaces. The COIs are responsible for the data, and establishing metadata, whereas the structure and the standards will be coordinated.

NCES has been conceived as a service oriented system, and this architecture paradigm sets its own perspective on the interoperability solution. Encapsulating the system functionality as



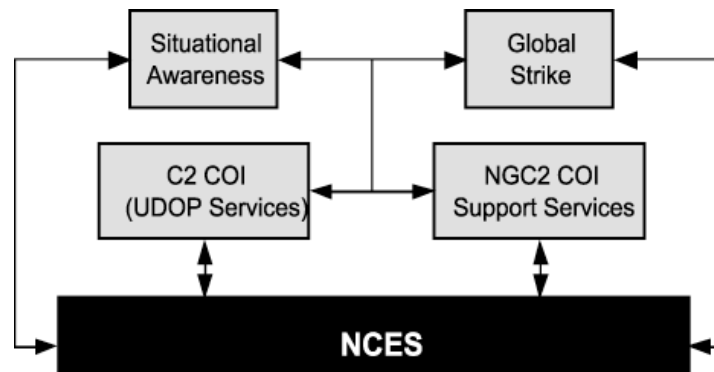
services, as the building blocks of the system, naturally places the interoperability problems at the service boundaries.

The Mediation Services is part of the Core Services, and provide a mechanism to disseminate, translate, aggregate, fuse, or integrate data and associated metadata for all NCES services. The NCES mediation concepts apply to data as well as metadata and services. Several types of mediation will be required including various forms of data mediation and service mediation. This paper addresses only the data mediation aspects.

Mediation is one of the key NCES capabilities, and it is based on the existence of standard metadata. Mediation resolves interoperability problems such as differences in the name, structure, representation, and meaning of data.

### ***Net-Centric Capability Pilot (NCCP) - Standard Data Transformation***

The NCC Pilot is intended as a showcase for a set of capabilities that cover the Core Enterprise Services from NCES, C2 services from UDOP (User Defined Operational Picture) and NGC2 (Next Generation C2) Support Services, and other developing Mission-oriented services under Global Strike, Situational Awareness, Intelligence, etc..



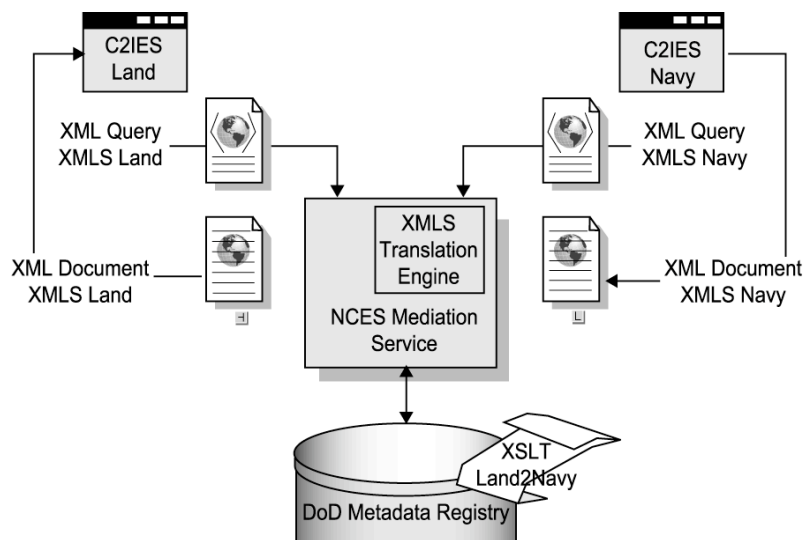
**Figure 2 NCCP Scope**

The NCES provides the basic set of services for all communities of interest (COIs). The core services included in the pilot are Information Assurance (IA) Security, Discovery, Messaging, Mediation, Storage, and Enterprise Service Management (ESM).

The NGC2 Support Services are shared among all NGC2 mission applications. They are not specific to a particular community of interest. Examples of these services are process management (including process orchestration) and workflow services.

The C2 COI services are specific to the Command and Control community of interest, and are shared by all applications across that community. The C2 COI services are also known as UDOP services. Examples are report management, track management, and entity management.





**Figure 3. NCCP Data Mediation**

The Situational Awareness services provide the DoD the ability to integrate all information necessary to support mission-specific decisions during concurrent planning and mission execution. The Global Strike is a specific instantiation of the Force Employment – air and space mission service. It involves planning and execution of strategic air platforms (B-52, B-1B, and B-2 aircrafts).

The NCC pilot is based on service oriented architecture (SOA) and is implemented using Web Services. There is a strong emphasis in using open standards such as Hypertext Markup Language (HTTP), Simple Object Access protocol (SOAP), and extensible Markup Language (XML). In some cases, legacy systems are wrapped by Web services.

The NCCP Data Mediation Service has a restricted scope (compared to the general requirements formulated for NCES) and is defined as providing “the ability to translate XML documents from a known source schema to a known target schema that reside in the DoD Metadata Registry using XSL mappings stored in the registry. The resulting schema can be another XML document, an HTML document, or any text-based document”.

The NCES Data Mediation Service is basically an XML transformation service. XML documents are transformed between NCES services using XSLT. The XML mappings are stored within the DoD Metadata Discovery Services (Fig 9).

The DoD Metadata Registry (DMR) is used here as the standard repository of XML translations. For the next releases, there are plans to allow the consumer service to denote the XSLT to be used and therefore to become independent on the DMR.

The translations have to be defined at the *design time* between each pair of communicating services. For each pair, translations have to be defined both ways. Defining such translations requires understanding of both data models and also familiarity with the application domains. In



other words, although this approach provides the advantages of simplicity, adherence to open standards, and takes advantage of an existent registry, it still requires considerable human intervention.

The approach taken by the NCCP pilot can be classified as a static data transformation between each pair of communicating systems. The transformation algorithms are defined at the design time, and cannot be changed dynamically at run time. Each data model has to be well understood by the developers, and each time the model changes, the data transformation algorithms need to be re-written. The development and maintenance of the NCCP data transformation service require considerable effort, particularly when new systems are added. The technical approach, using XML and XSLT, remains to be validated by relevant practice. Although the popularity of these technologies is overwhelming, relying only on them can create scalability problems in the case of large data models or complex communication schemes.

## **Defining Scalable Models - basics**

We need a data model that specifically addresses the interoperability between different data models at more abstract levels. Without it any attempts to solve interoperability problems risk to be inconsistent, partial, and difficult to generalize for new data models. We need a model that can be applied to all data operations that take place in the systems: searching, retrieving, accessing, interpreting, aggregating, fusing, mapping, etc. Most data models were invented for operations that didn't involve data interoperability, for operations such as accessing and retrieving from known data sources. Interoperability issues appear when data sources are not necessarily known, and when the format and content of data are different or even unknown at the design time.

One approach to address the complexity of such encompassing data model is by defining levels (or layers) of data interoperability. This is not by any means a new type of approach. It can be found in the network and web protocols (TCP, IP, HTTP, SOAP, etc.), or in the semantic web data language stack (XML, RDF, OWL, etc.). What makes this approach different is its application to data modeling. [Melnik2000].

In this paper we are referring to the data mediation issues, but this approach can apply to other services as well. The objective of this approach is to provide a clear distinction between data mediation services offered at different levels. The services can be layered on top of each other, enabling a stack of services on top of more basic levels.

The main idea is to separate data from its usage by creating intermediate layers of data descriptions, or metadata. The metadata can describe both the data structure and its usage. The applications access data indirectly, by using the associated metadata. If more than one application will access the same data, then the metadata has to be represented in a common or standard way, so that all applications can understand it.



From a theoretical point of view, there are at least three different levels of abstraction for data modeling: structural, ontological and operational. At each level data models can be constructed and expressed by using specific languages and tools.

## **Structural Level**

At the structural level, the data model comprises sets of elementary syntactic data elements that are composed in arbitrary higher level structures, so that data can be efficiently accessed and retrieved. The reasons why data has been organized in certain ways are not explicitly contained in the model. The data structuring reasons or data semantics is implicitly represented by the processes that use the data. Any applications that exchange information at the structural level needs to preserve the initial structure, so that the information can be meaningfully exchanged back and forth.

One of the most efficient and simple syntactic mechanisms to structure data is tagging (or naming) data. This is done by using markup languages. XML (eXtended Markup Language) has become pervasive, its use extending really beyond its initial goal of describing web pages. To reconstruct exchanged data objects and their relationships used in the structural layer, the description of the data structure is obviously necessary. Rather than writing application code to interpret each particular structure, a standard (semi-) structure description language can be used instead. For example, the XML schema language can be used as the standard for describing or documenting the data structures.

Mediation at the structural level transforms data having the same meaning from one syntactic representation to another. The data structures may have the same names but differently arranged, or they may have different names, but a mapping is always possible.

The data mediation services offered at the structural level is basically data transformations between different representations. Mapping data from multiple and diverse sources into different data formats represents a basic set of functionality. The semantically correct and complete creation and interpretation of the mappings is a highly nontrivial process. The mapped models include structured models such as relational or object oriented, and semi-structures such as XML. The current state-of-the-art of the technology for such mappings is represented by tools that generate trivial mappings across relational schemas, the users having to manually identify and specify some more difficult or impossible to automate details.

## **Ontological Level**

Semantic interoperability requires standards not only for the syntactic form of the data but also for the semantic content. The semantic models include explicit descriptions of the data elements semantics. Semantic data models emerged from the requirement of having more expressive conceptual data models. The semantic models are always considered as such by comparison with some other models that capture less information about the application domain.



The semantic models have been recently denoted as ontologies, following the Semantic Web terminology. An ontology constitutes a formally defined and represented encyclopedia on a given subject domain. The ontology spectrum varies from controlled vocabularies to highly specialized domain models. Ontologies are application independent, specified in a standard modeling language. Formal ontologies are specified using representations languages that can be used for automated reasoning. For instance, the Semantic Web language for ontologies is OWL [OWLSpec].

Due to their formal representation (here formal means machine understandable), ontologies are data models that can be reused across systems and applications. Their distinctive feature is to address the interoperability problems at a higher degree of abstraction.

In fact, both syntactic models and semantic models are simultaneously needed, not in the least due to the fact that they serve very different purposes. The semantic models provide domain abstractions, while syntactic models enforce structure on the information sources. There is always a degree of overlap between the two approaches, as the semantic models of the day become the syntactic models of yesterday (XML has been introduced as the miracle semantic tool at the time), and as a result it is sometime confusing to clearly separate the two.

## **Operational Level**

Interoperability at the ontological/semantic level is not always possible. The question is what degree of semantic overlapping is necessary to achieve interoperability between two systems. The answer can be given by the specification of the operational need for interoperability.

For instance, military interoperability occurs when different military services (air, navy, land) act in a combined fashion and also in the international context of coalitions. Each developed C2 systems that suit their specific needs. They share some elements that might be shared by their distinct ontologies. The shared elements may be represented differently, but they do exist in both systems. For instance, in their respective ontologies, the details about the spacecraft types may differ from the land component to the navy component. These information elements cannot be exchanged as such. Therefore, the mapping process has to determine that there is sufficient conceptual compatibility between the information elements, so that they can be safely used. The operational context is the driving force and rationale for this kind of semantic interoperability. In other words, the mapping can be considered acceptable, provided that the operational concept is still conveyed between the systems.

NOTE: It is very important to establish standard connections between data modeling levels.

## **Conclusions**

Achieving data interoperability is a highly non-trivial process. Different interoperability contexts come with different interoperability problems, which at their turn may be solved using different methods and tools. Various models for data interoperability can coexist and in fact should coexist within a complete solution. The challenge is to appropriately define levels or layers of



interoperability within a given system, from no interoperability at all to highly complex interoperability.

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Multilateral Interoperability Programme

# ***Multilateral Interoperability Programme (MIP)***

## ***Coalition Sharing of Information in Context***

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1

### ***MIP Mission/ Objective(s)***



Multilateral Interoperability Programme

- Aim: Achieve international interoperability of Command and Control Information Systems (C2IS) at all levels:
  - Corps to battalion, or lowest appropriate level
  - Support multinational, combined and joint operations
  - Advance digitization in the international arena including NATO
- Scope:
  - War Ops, Crisis Response Ops, Defence Against Terrorism
  - Joint, Interagency, Multinational, Non-governmental Organizations
  - Tactical to Operational and Strategic levels

2



## MIP Defined



Multilateral Interoperability Programme



- What it is and what it provides:
  - Materiel / Combat developer forum Driven by national doctrine and requirements
  - Venue for international interoperability testing
  - Coordinates synchronization of materiel fielding plans
  - System-independent capability based on information interoperability

3

## MIP Defined



Multilateral Interoperability Programme



- What it is not:
  - A typical cooperative development program:
    - No common funding
    - No single Program Manager
    - No common hardware or software development
  - Organization specific, e.g., NATO, PFP, ABCA . . .

Bottom Line: MIP is a functioning successful C2 Community of Interest


















## Current MIP Membership - Corps & Below C2IS



### FULL MEMBERS

	CA	LFC2IS
	DA	DACCIS
	FR	SICF, SIR
	GE	HEROS-2/1
	IT	SIACCON
	NL	ISIS
	NO	NORTaC/NORCCIS
	SP	SIMACET
	UK	ATacCS/ComBAT
	TU	TKKBS
	US	MCS

### ASSOCIATE MEMBERS

	AS	JCCS, BCSS		RO	TBD
	AU	PHOENIX		SI	TBD
	BE	SICBEL		SW	IS MARK SLB
	CZ	GF-TCCS		AFNORTH	
	FI	TBD		ACT	BiSC AIS
	GR	HARCCIS			
	HU	HAVIR			
	LH	TBD			
	PL	SZAFRAN			
	PO	SICCE			

5

## Organization Members / Systems



### FULL MEMBERS

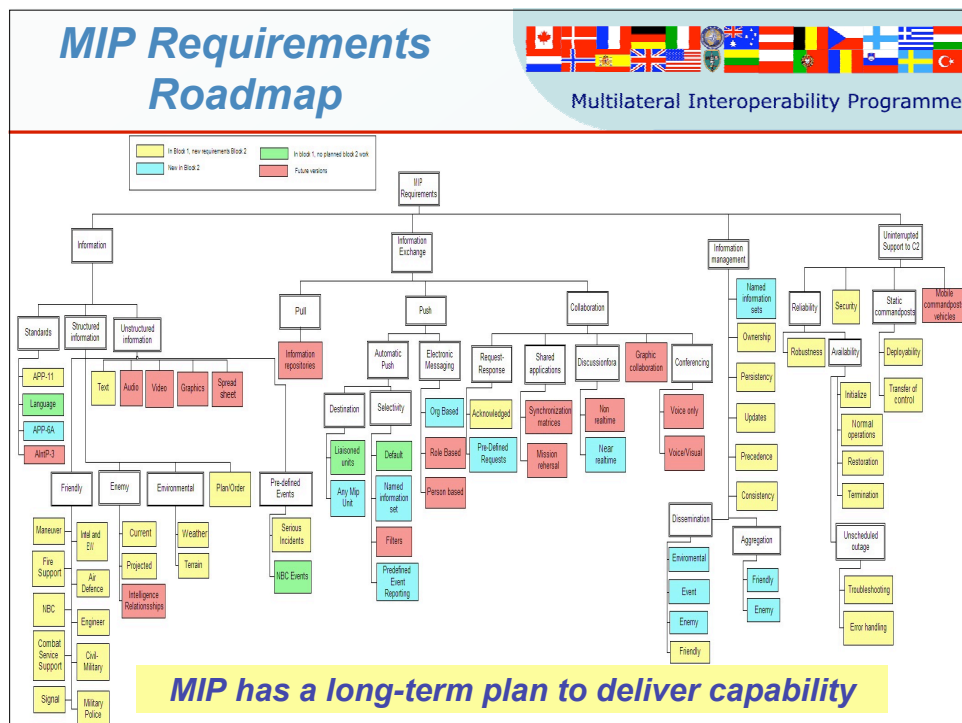
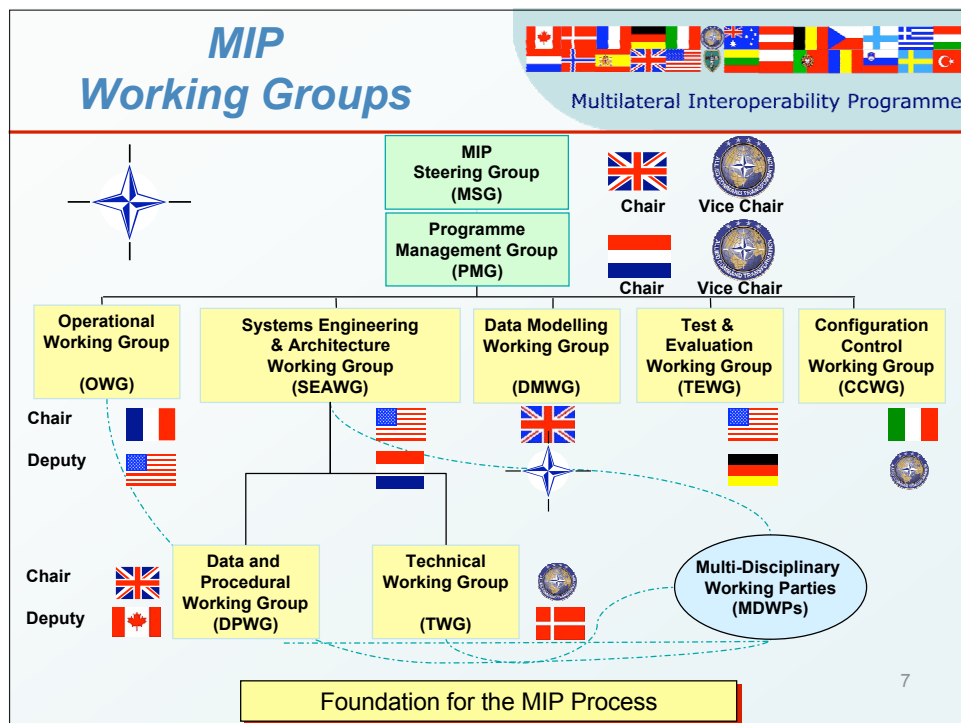
	CA	LFC2IS
	DA	DACCIS
	FR	SICF, SIR
	GE	HEROS-2/1
	IT	SIACCON
	NL	ISIS
	NO	NORTaC/NORCCIS
	SP	SIMACET
	UK	ATacCS/ComBAT
	US	MCS

### ASSOCIATE MEMBERS

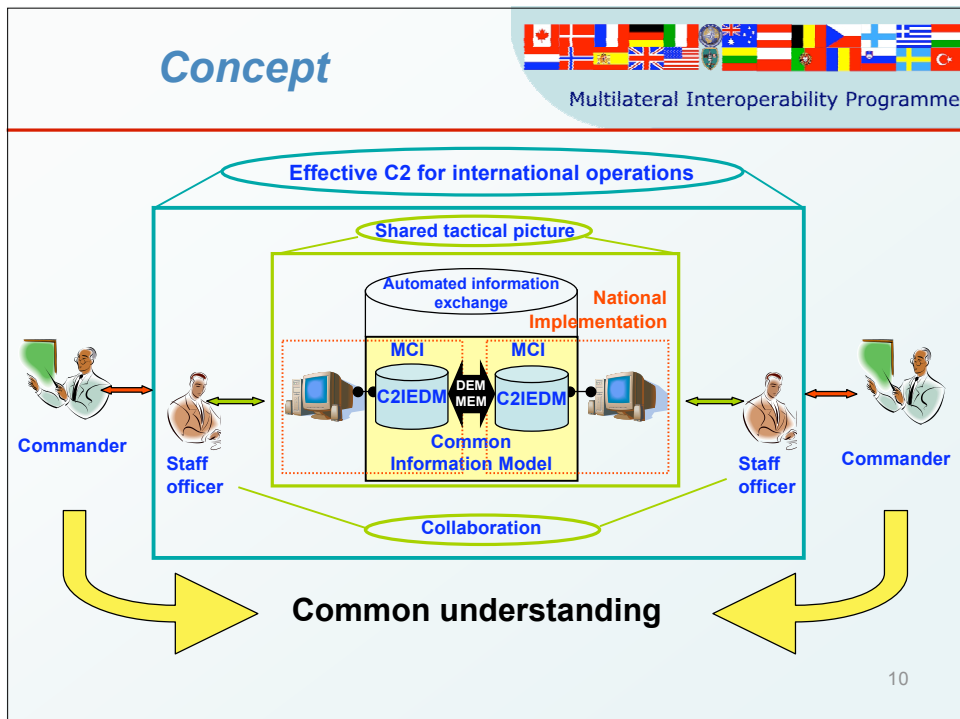
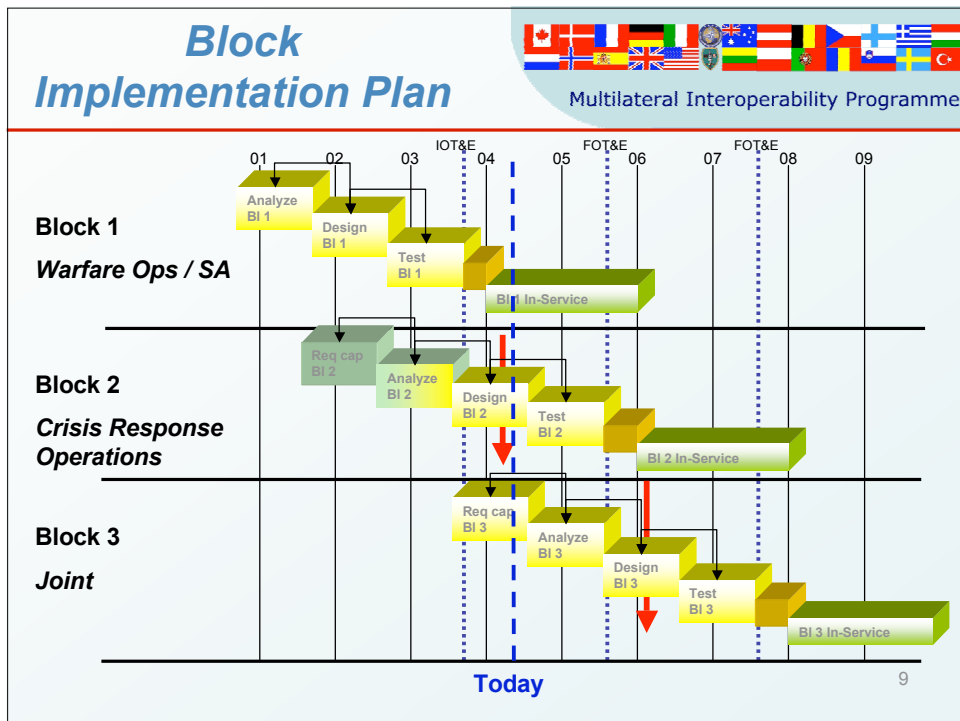
	AS	JCCS, BCSS		RO	TBD
	AU	PHOENIX		SI	TBD
	BE	SICBEL		SW	IS MARK SLB
	CZ	GF-TCCS		TU	TKKBS
	FI	TBD		AFNORTH	
	GR	HARCCIS		ACT	BiSC AIS
	HU	HAVIR			
	LH	TBD			
	PL	SZAFRAN			
	PO	SICCE			

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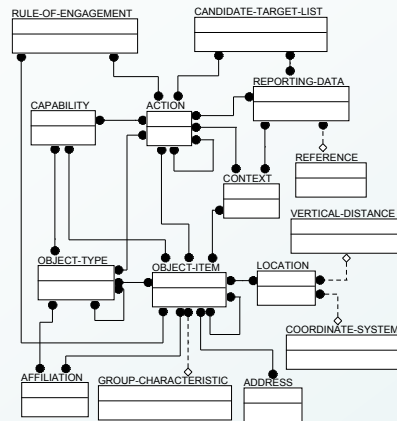




## Concept - C2IEDM



Multilateral Interoperability Programme



- GH → LC2IEDM → C2IEDM → JC3IEDM
- Automated C2 Interface Exchange Mechanism To Support Liaison and Automation
  - Exchange Of Orders/Graphics
  - Holdings/Status Information
    - e.g., AD Weapons Control & Running Status
- Operational exchange standards use a common vocabulary consisting of 176 information categories that include over 1500 content elements.
- Information Exchange Data Model
- Serves as a Hub for functional areas
- CRO & Joint IERs

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## MIP Path Forward



Multilateral Interoperability Programme

- MIP has established a basic capability for exchange of SA data in Block 1
- MIP has a path forward based upon a defined set of functionality enhancements in a block implementation scheme
- We've identified the need to define MIP Operating Procedures that need to be incorporated into national unit/TOC SOPs
- We've begun to realize the impact on ways of doing business/culture
- Need to investigate and plan for evolution in warfare in the information age

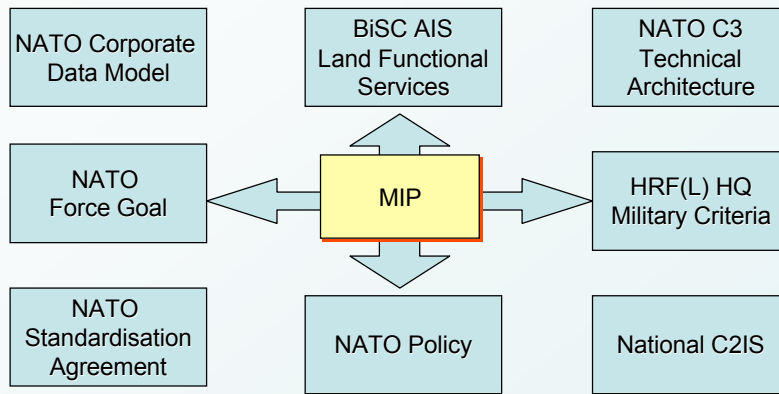
12



## MIP Acceptance



Multilateral Interoperability Programme



MIP has Gained Wide Acceptance within NATO as a Foundation for Policy, Standards, Specifications and Systems!

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## Other US Stakeholders – Efforts that Leverage MIP

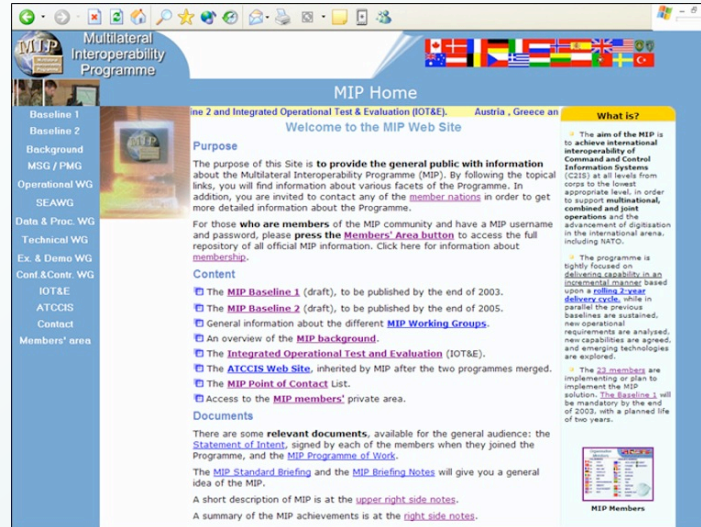


Multilateral Interoperability Programme

- **GIG**
  - J6I has identified C2IEDM / MIP addresses Key Interface Profile #17
  - Identified as applicable to User Defined Operational Picture (UDOP) COI
- **ABCS**
  - Current US MIP implementation program is Maneuver Control System
  - Implementation on-going in MCS 6.4 GE
  - Planned software reuse - other ABCS programs
- **Army Future Combat Systems (FCS)**
  - MIP can be leveraged to satisfy coalition interoperability requirements
  - C2IEDM integral to FCS data strategy
  - MIP FCS MOA in process.
- **FIOP FY04 program initiative**
  - Single Integrate Ground Picture (SIGP)
  - Situational Awareness Data Interoperability (SADI)
- **Shared Tactical Ground Picture (STGP)**
  - US, UK and Norway interoperability project
  - MIP listed as "Quick Win"
- **DISA XML Registry: Coalition Namespace**
- **CIO/G-6: C2IEDM foundation for Data Strategy**
- **Foundation piece of the DJC2/JC2 Strategy**

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# **The C2 Community of Interest (CoI) as the Foundation for Joint, Multinational, and Inter-agency Interoperability**

**Erik Chaum**

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Good afternoon, it's my pleasure to be here today to help discuss interoperability and in particular why the many and varied military functional communities-of-interest (CoI) must build on a common Command and Control (C2) core set of concepts and semantics. Interoperability is a fundamental capability required in net-centric operations, military systems and services. I am going to assert that the work of the Multilateral Interoperability Programme (MIP) and in particular the Command and Control information Exchange Data Model (C2IEDM) can serve as a baseline for joint, multinational and interagency C2 interoperability.



## **Presentation Themes**

- **They way things are**
- **The way we want things to be**
- **Implications**

To do this, let's consider how things are, how we want them to be, and the implications that arise.

I'll start with a question; what part of the house is most important the foundation, the walls, or the roof? In truth they are all important; they all have to be well designed, they all have to be well built, and they all have to be well integrated. Which one do you build first? The message, there are usually many important parts to any endeavor but determining and establishing the *foundational* parts first is critical! The net-centric operations/warfare (NCO/W) future that we are working to build is completely dependent on getting interoperability right. Getting it right will mean getting it fundamentally different! This is in large part why the US Department of Defense vision speaks about *transformation* and not just *change*.

Interoperability is an operational and technical quality that enables entities to effectively and efficiently works together. At a most fundamental level, interoperability requires a capability to unambiguously exchange and correctly process information. The essence of being networked requires both a capability to communicate and understand - otherwise you are on the network but not networked. These two capabilities are required within any entity (man or machine) that expects to participate in a distributed integrated process, e.g., military functional/mission operations.





## Interoperability

- **Interoperability is an operational and technical quality that enables entities to effectively and efficiently work together.**
- **At its most fundamental level, interoperability requires a capability to unambiguously exchange and correctly process information (being networked).**
- **Joint vision; ubiquitous interoperability, automated information exchange, and smarter applications/autonomous entities**
  - **Good decision-making requires knowledge of, and the ability to reason about, operational context**

When I first read and was trying to understand the DoD Joint Vision, I learned that the envisioned capability was dependent in large part on 1) ubiquitous interoperability, 2) automated information processing, and 3) smarter and more useful warfighter decision support (which might be manifest as intelligent agents, applications, or autonomous systems). The Joint Vision seeks to use information technology to achieve these three complementary capabilities. The much-touted faster, smaller, cheaper processors and network hardware alone will not provide the desired set of capabilities. So what is required to achieve the vision?

Warfighters require knowledge of the operational context in which they operate in order to make well-informed and appropriate decisions. Thus, it follows that sophisticated decision support systems (regardless of type) will also require access and the ability to process operational context information/knowledge. Therefore the envisioned future net-centric warfare capabilities depend in significant part on our ability to formally represent and share operational context information/knowledge between warfighters and with and between our decision support systems. In the NCO/W environment “sharing” explicitly requires the automated ability to process the information exchanged even when it comes from *a priori* unknown sources.

As an example, sensor-derived track data is absolutely essential and completely insufficient to conduct coordinated air defense operations. A decision support system to aid a Tactical Action Officer should, before it recommends a specific tactical engagement, know if “weapons are free”, what air space coordination measures are in effect, the air tasking orders, local commercial airline transit routes and schedules, reported friendly aircraft and ships tracks, other organic and off-board track reports/estimates, the status of other air defense capable forces, and many other contextual factors. Much of this and other relevant contextual information will come from off-board the ship, from Naval, Joint, multinational and international sources.

How then do we represent and share operational context? If we can’t do it effectively then our ability to cooperate, interoperate, and synchronize will be limited and the vision will remain unrealized.





## **They way things are**

- **To build military collective capability we train military personnel**
  - Core + specialty training
  - Community then Service then Joint
- **To build military collective capability we integrate information systems**
  - Expensive to build and maintain
  - Ambiguous and incomplete information exchanges limit effective interoperability
  - Unstructured exchanges limit aided information processing

How do we build interoperability today? To start with we build military communities by training personnel to give them a shared understanding of domain knowledge; a shared set of operational concepts, semantics, and key domain relationships. There are core sets of ideas that all military personnel learn, e.g., military ranks, the concept of the commander and subordinate, etc. Functional area training builds on the core domain knowledge. By going through the same schools and processes we develop a military team that is prepared to effectively work together.

Fielding military capability requires integrating systems and that is typically expensive to do and maintain. To build a successful and robust interface between two systems a well-defined interface, strictly adhered to by both systems, must be established. It must precisely define what will be shared, what it means, and what business rules are associated with the information and the business process/protocol. If either side doesn't fully appreciate/understand it, or correctly implement the interface, then eventually that system, and associated process, will fail under some condition. This is just as true in today's service oriented architectures as it is in a point-to-point interface.



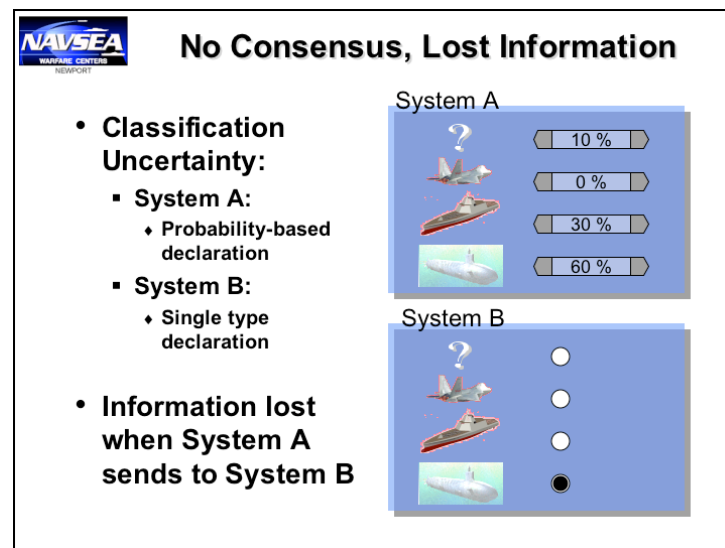
## **Consensus Today**

- **Consensus is today, as it has always been, the basis for any robust interface.**
  - A software interfaces must be well defined and adhered to in order for it to function reliably.
  - Consensus must be built.
  - Technical consensus is limited by choices made during the design process. Thus, interoperability is likewise limited.
- **Types of exchanges:**
  - Lossless
  - Incomplete (dark metadata)
  - Information lost



Which data and operational context information can be exchanged between any two systems is determined by what those systems know how to represent, i.e., entities can only effectively communicate that which both understand. In this “information space” overlap ambiguous and incomplete information exchanges are however prevalent. Limited interoperability is likely to occur when systems are built on different semantic baselines.

There are only two results when exchanging information, either the information passed is completely and properly understood, or not. When the exchanged information is not completely understood it can be due either to filtering (“dropping” what is not understood) or misinterpretation.



As an example, consider two data fusion systems each of which has independently developed a way to represent the concept of *track classification uncertainty*. In system Alpha track classification uncertainty is represented using a probability construct, e.g., Track S001 is a vessel of submarine type  $p=60\%$ , surface craft type  $p=30\%$ , unknown type  $p=10\%$ . In system Beta track classification uncertainty is represented as one, and only one, option from an enumerated list, e.g., options are unknown, air, surface, or submarine. Both of these representation concepts and semantics are fine on their own. However, when system Alpha tries to send “Track S001 = 60:sub/30:surf/10:unk” to system Beta what happens? Information is lost! There is no loss-less result possible because the concepts and semantics within the two systems are not equivalent. Additionally, limited interoperability is likely to result in higher integration, testing, and updating costs.

In the previous simple example we see why DoD is working to move away from point-to-point (i.e., system unique interfaces) and to functional/mission CoI-defined domain concepts and semantic standards. In a CoI standards-mediated world, the warfighters define the relevant CoI concepts and semantic needed and all CoI systems and services implement to the CoI standards. Conforming systems use the CoI data model, metadata, taxonomies, and ontologies, and are by design compatible at the semantic/information level. They are, in this critical respect, ready to interoperate and deliver capability as part of a distributed integrated CoI warfare process.





## Today's Myths

- **Our system engineering experience has led us to believe a number of myths:**
  - **Translation / mediation are good enough for exchanges between most systems**
  - **There is only a small common core of information that everybody requires.**
  - **Standards haven't worked**
  - **XML is the answer**
- **A fundamentally better outcome will result from the same repeating the status quo.**

Translation, or mediation, may seem like a reasonable alternative to a difficult consensus process and seeking semantic alignment within CoIs. DoD's net-centric enterprise services (NCES) include a mediation service concept – a service that converts from one representation to another. Where formal lossless translations exist (e.g., JPEG to TIFF) mediation is practical and useful. However, much of the time as in the *track classification uncertainty* case above, mediation will not provide fully acceptable results. In the short run, as legacy systems evolve to comply with CoI standards they will translate to communicate and the limitations discussed above will apply. In the longer-term, the CoI-approach requires semantic alignment at the interface and internal to systems and services.

What is the scope of the information/operational context that we need to understand and exchange? Is it a small or large set of information? The consensus-based standardization efforts of the Multilateral Interoperability Programme (MIP) give us an important “data point”. In the MIP experience diverse Army communities did not *a priori* believe they would have much in common. The consensus process led to the realization that there is perhaps as much as a 90% overlap. In other words, there is a large common core of military operational context information/knowledge that all commanders need to share in order to conduct effective coordinated operations.

Why haven't previous standards worked to achieve interoperability? Standards do work, however, there are many aspects to standards specification, interpretation, and implementation that can lead to technical failure. Perhaps equally important there are many organizational, business, and social aspects to standards development and adoption that can prove to be impediments. There is no substitute for standards, however, in the NCO/W environment we require a new standards paradigm to ensure that dissimilar, distributed, systems and services can be integrated/composed. Internet IP protocols, and service-oriented architectures are part of the solution. System-independent CoI information exchange standards are equally a critical foundational layer in our new enterprise paradigm/architecture.



The MIP 2003 Integrated Operational Test & Evaluation (IOT&E) was an example of interoperability based on system-independent CoI information exchange standards. During the IOT&E twelve Army operational and tactical systems from eleven countries were integrated and tested. Each of these systems was built independently to national functional/mission requirements. Underlying this impressive CoI capability was a twelve-year, 24 nation, ~\$100 million (each nation funded their own participation) effort to build operational and technical consensus. What is different and important about the MIP effort is that the investment is not locked inside a few proprietary systems and unique interfaces, but rather, it is published for reuse as an open international standard. DoD can't afford to start over and we need to be interoperable with our allies. Thus, we must consider the work of the MIP as an important point of departure for both Combined and Joint interoperability.

Extensible Markup Language (XML), much touted as the new *lingua franca*, is not a complete interoperability answer. XML provides a syntax. What is more important is the domain namespace. The domain namespace definition process requires a community to build consensus on what concepts and semantics are important to the community, its business processes and supporting information exchanges. The MIP's multinational process has built such a consensus and documented it using the C2IEDM (along with the thousand pages of accompanying documentation). The C2IEDM effectively documents a domain namespace and in turn can be used to autogenerate the corresponding XML namespace schema (XSD). With regards to XML, the hard part is the semantic consensus process and the easy part is the XML (XSD) definition. To alternatively implement system-unique XML schema is to reinvent the point-to-point translation approach, i.e., XML does not solve the "Alpha to Beta" interoperability problem described earlier.



### The way we want things to be


- **Information age concepts and capabilities applied to warfighting & business operations**
- **C2 agility and mission tailoring**
  - Joint and Combined
- **Ubiquitous information, & knowledge sharing**
  - Task, Post, Process, and Use (TPPU)
  - Discovery and Pull
  - Interoperability through "data" and meta-data standardization [multi-national, joint, interagency]

**Improved Coordination of Forces / Coordinated Operations**

An underlying joint and combined capability objective is to improve our ability to effectively coordinate and synchronize diverse forces, from the operational to tactical level. Information technologies and concepts are applicable to the way DoD does business. We expect these technologies to enable capabilities that empower the warfighter and war fighting process in part through greater operational and tactical agility and flexible mission tailoring. Ubiquitous



information and knowledge sharing will be realized through a new set of services that enable entities to post and discover CoI information in a timely manner. To get this fundamentally better interoperability outcome we need a fundamentally better joint and multinational information exchange consensus definition process.




## Transformation

- **Start with:**
  - People
  - Process
  - Policy
- JV > NCO/W > GIG > Fn

- **GIG (and WWW) “Data” Strategy:**
  - **Community of Interest (Col)**
    - ♦ Shared ontology, data models, metadata, taxonomies, schemas, business rules
    - ♦ Shared semantics and domain values
    - ♦ Externalizing and reusing domain knowledge
  - **Understandable (Semantics and Syntax understood by applications and user)**

“Transformation” is a DoD watchword today and is intended to convey the expectation that we will, as an organization, be fundamentally different and better after the change. Joint vision, net-centric warfare, GIG, and FORCENet are all intimately coupled to this envisioned transformation. They are not so much different futures as they’re different views on the same objective future. The published GIG data strategy for realizing interoperability is to organize about the concept of communities-of-interest, instead of about systems. As already mentioned, this is very similar to the World-Wide-Web Committee (W3C) XML namespaces concept. The GIG data strategy is explicitly based on CoIs and specifically shared data models, ontologies, metadata, and taxonomies. The development of shared semantics and domain values is a critical part of publicly, and in a system-independent manner, defining and reusing domain knowledge. It can serve as a basis for open source components reducing development, testing, and integration costs. It also enables a key objective of the data strategy that is to create semantics and syntax that can be understood by both the warfighter and the decision support applications.




## DoD Data Strategy Goals

- **Information Interoperability:**
  - **Increase use of enterprise and community data**
    - ♦ Visible
    - ♦ Accessible
    - ♦ Institutionalize
    - ♦ Trusted
  - **Decrease use of private & system data**
    - ♦ Use Col standards to publish on the GIG
  - **How do Col interact / interrelate?**



The GIG data strategy interoperability goals also include making information more 1) visible, 2) accessible, 3) institutionalized and 4) trusted. To do this we must at the same time make it less proprietary and system-specific and instead migrate to CoI standards - which will address the first three objectives. Sharing the rich set of operational context information through CoI-based services will enable developers to build a new and more useful generation of mission capabilities.

But how do the various CoI interact and or interrelate?



## Implications

- **Consensus-based standards**
  - No system, Service, or process is an island
  - Translation for current capabilities is a transitional step, fuller semantic alignment & reuse is the goal.
  - Service, application, process, information service, technology, vendor independent information exchange
    - ♦ Shared information services
  - Business value added:
    - ♦ Little value in unique battlespace representations
    - ♦ High value in being able to exploit and reason about the community view.
- **But is there one standard?**

In our net-centric world, no system, service, or process is an island. Each must interoperate with other CoI capabilities on the network. Ideally, no semantic translation should be required enabling easy and correct processing of information. In turn this helps ensure that integrated distributed mission capabilities can be seamlessly composed. In our transformed world commercial entities can make money by enabling systems and services to successfully join and support functional/mission CoIs. In a CoI-organized world building unique battlespace representations and information exchange interfaces is a low value-added activity. The high value-added activities are learning the CoI semantics and applying operational context to better meet warfighter decision support/system/service needs. Note that within a given system the “physical” representation of the CoI data model (and other CoI standards) can be tailored, as is required, to meet the implementation needs of the application or user. Thus, the CoI approach does not limit a developer’s local design choices, except at the interface where interoperability must dominate.

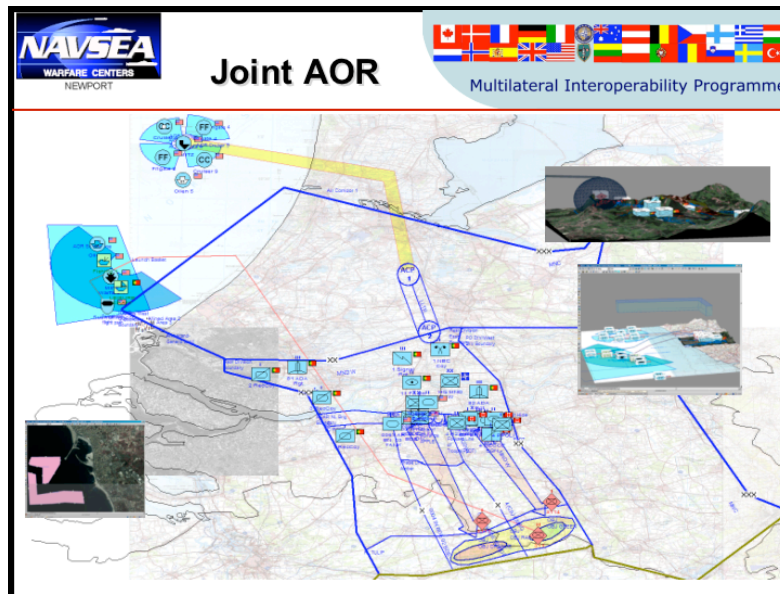
Can there really be one standard CoI? No, but . . .







perspective where is antisubmarine warfare (ASW) in the joint mission capability packages? In the joint world there is no ASW, rather ASW must be seen as supporting and drawing on Force Protection, Situational Awareness, Intelligence, etc. As we implement JC2 we need a C2-core “information backplane” that spans the joint set of mission areas and is rich enough, and generic enough, to integrate across the mission areas. The C2IEDM can serve as the C2-core baseline and the information backplane in the next generation of NCO/W systems and services.



To showcase multinational consensus-based standards, OSD (AS&C) sponsored, twelve demonstrations of MIP/C2IEDM CoI capabilities at DISA and Joint Forces Command. Canada, Portugal and the United States Army teams were brought together and their MIP-compliant national systems (used also at the MIP IOT&E) were integrated and run through an operational/tactical scenario. The two maritime sets of control measures (submarine operating area with Tomahawk Launch Basket and route, and Carrier Battle Group Screen) and tracks were not in the original scenario. They were quickly and easily specified using the Portuguese ground tactical system, which uses C2IEDM as its “information backplane”. The C2IEDM already has generic semantics for control features and metadata, e.g., associated organization. Once entered this information was immediately exchangeable with the C2IEDM CoI-complaint Canadians and U.S. systems!

Additional notes -----

This example of extensibility and interoperability, based on C2IEDM, shows the power and efficiency of CoI consensus-based concepts and semantics. These views of SICCE are meant to show the existing Joint nature of the C2IEDM. Using the Army-defined control measures these typical naval control measures were easily represented using C2IEDM. You see here a:

- naval aircraft carrier battle group with a screen formation
- submarine operating area in the lower left corner
- Tomahawk land attack missile launch basket (declared appropriately as a “weapons firing area” in the C2IEDM)



- starting from the submarine location the Tomahawk flight route to the target
- defensive naval minefield protecting a port.

SICCE can show the situation in both 2D and 3D as requested by the operator.


It is important to emphasize that what is shown is not simply a graphic but rather a graphical representation of information in the C2IEDM data base.



### This is Transformational

- **The C2IEDM is not an application, or agent technology, or web service (A/AT/WS)!**
  - It is a view of the foundational knowledge required to make A/AT/WS Better!
  - It is a technical foundation enabling transforming interoperability from point-to-point to Col-based.
  - It captures the warfighter operational consensus required to build technical solutions that are operationally, semantically and referentially meaningful and complete.
- **The C2-core Col gives us a path to Joint, Combined and Inter-agency interoperability**

The C2IEDM is not an application, it is not an agent technology, and it is not a web service. It does however capture war fighting operational consensus and the foundational domain knowledge required to make these kinds of capabilities better. As a well-defined and internationally vetted C2-core, the C2IEDM gives us a good path to joint, combine and interagency interoperability.



### Transformations

• Not just a technical alternative	➔	• Consensus-based semantic alignment
• Not technology led	➔	• Warfighter led
• Not system led	➔	• Mission / Col led
• Not new a stovepipe	➔	• C2 cross-cutting/ integrated
• Don't start over	➔	• Leverage

Better, Faster, Cheaper



This move to semantic alignment must be warfighter led. The foundational operational and technical consensus work of the MIP, resulting in the C2IEDM, can accelerate this fundamental change. It creates a technical foundation, enabling and accelerating the type of transformational interoperability we seek. It moves us from point-to-point to community-of-interest-based information exchange capability. It may only be an 80% solution to our C2-core operational and tactical exchange requirements, and each CoI will need to extend it to some degree, but 80% is a pretty good place to start. In this new paradigm, our goal can and should be *better, faster, and cheaper*.

Author Bio:

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chaume@npt.nuwc.navy.mil



## **Operational Modeling & Simulation Services in Military Service-oriented Architectures**

### ***A White Paper summarizing related Concepts***

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### ***Overview***

The idea of Net Centric Warfare as described in D. Alberts and R. Hayes Command and Control Research Program (CCRP) book “Power to the Edge” focuses on organizational networks. It is computer nets and grids that enable the necessary communications and knowledge exchange being the technical prerequisite for efficient Net Centric Warfare. The current software paradigm to cope with these challenges is to apply services within service-oriented architectures (SOA). SOA is a collection of composable services. A service is a software component that is well defined, both from the standpoint of software and operational functionality. In addition, a service is independent, i.e., he doesn't depend on the context or state of any application that calls it. Currently, these services are typically implemented as web services. Services in grids are often referred to as grid services. Although different standards may be used for the implementation of the service, web services and grid services are used as synonyms in this paper. The advantage of using web standards in an SOA is that the services can more easily adapt to utilize distributed applications in heterogeneous infrastructures. Nothing in particular has to be done programmatically to the service, except to enable it to receive requests and transfer results using web-based messaging and transportation standards. In many cases, web services are straightforward and existing software can easily be adapted to create new web services usable within an SOA.

The use of Modeling & Simulation (M&S) applications to support the warfighter is an established requirement. However, in system-centric environments solutions are likely to be interface driven and point-to-point solutions with only a limited potential for reuse. With the advent of SOA and their application, a real common heterogeneous information infrastructure for Net Centric Warfare with embedded operational M&S functionality is feasible.

This paper will motivate the use of operational M&S services for the warfighter, will introduce the common concepts of services, and gives examples on how M&S services can be integrated into future grid-based Command and Control systems. It is a white paper collecting various ideas and gives references to papers and presentations with the necessary academic depth. It was written to give an overview and refer to papers detailing underlying technical challenges and solutions. This paper summarizes the ideas of the papers listed in the reference section.



## Operational Requirements

The operational requirement for a closer integration and the migration towards a common information infrastructure are rooted in the ideas of Net Centric Warfare. While the use of simulation to support the warfighter directly and indirectly via training simulators and simulation systems, the use of simulation within procurement and acquisition, training for analysis of equipment, organization, and doctrine, experimentation to support the transformation of the armed forces, and even to some limited degree the support of real operations is established, the idea to embed operational M&S components into real command and control systems to deliver immediate support as decision support tools is still quite new.

This view changed with the advent of Net Centric Warfare. Net Centric Command and Control operations postulate that the more information we can collect, create, and share about the adversary, the operational environment, our capabilities, readiness, and logistics, the more we can focus our capabilities to produce desired effects with less risk of unintended consequences and more efficient expenditure of national resources. This migration to an information sharing and dissemination system will need to include both a hierarchical (to accommodate military Command and Control doctrinal functions) and a peer-to-peer ability to share and access information and functionality between all levels in the Command and Control system. This new capability is required to enable sharing of unprocessed or uncorrelated raw data with selected users on demand, and allows distributed functionality of advanced collaborative planning, coordination and decision support applications. Further, with this advanced information flow and accessibility, intrinsic Command and Control applications to enable "sense making" of information overload and for tailoring a Command and Control node to a specific purpose or role become apparent. This new role for Net Centric Command and Control requires applications traditionally found in the M&S community. They must be integrated into Command and Control and will perform an important function in the enhanced capabilities of the Joint Command and Control (JC2) system of the future.

In order to discuss and measure the increase in efficiency, the Net Centric Warfare quality value chain introduces the levels of data, information, knowledge, and awareness quality.

- The value chain starts with *Data* Quality describing the information within the underlying Command and Control systems.
- *Information* Quality tracks the completeness, correctness, currency, consistency, and precision of the data items and information statements available.
- *Knowledge* Quality deals with procedural knowledge and information embedded in the Command and Control system such as templates for adversary forces, assumptions about entities such as ranges and weapons, and doctrinal assumptions, often coded as rules.
- Finally, *Awareness* Quality measures the degree of using the information and knowledge embedded within the Command and Control system. Currently, awareness is explicitly placed in the cognitive domain.

Command and Control needs quality support on all levels. The underlying assumption is that the quality of Command and Control itself will be improved by an order of magnitude when a new level of quality is reached in this value chain. This can be explained as follows:



- Data quality is characterized by stand-alone developed systems exchanging data via text messages, such as the U.S. Message Text Format. Standardized data exchange ensured the data flow, but every system had to interpret the data in its own and individual business rules, which often led to different interpretation of the same data in different systems. Until recently, this was the best information technology (IT) could do.
- The federated systems using the Common Operating Picture (COP) resulted in an order of magnitude improvement of the Command and Control quality. Instead of common data, the staffs share common information, as data is displayed in context. The COP enables them to work more effectively and more efficiently. This is the state of the art of IT support. The Command and Control Research Program (CCRP) of the US DoD supported experiments showing that the COP really resulted in better Command and Control decision than data driven solutions.
- The next step, which is enabled by service-oriented web-based infrastructures (but not yet operationally used), will be the use of models and simulations for decision support. Simulation systems are the prototype for procedural knowledge, which is the basis for knowledge quality. Simulation systems can be used to evaluate alternative courses of actions, to deliver orders and the commander's intent. One of the main challenges of Command and Control is the dynamic and agile battle management. Dynamics and agility are characteristics of simulation systems, or, in other words, dynamic and agile battle management results in the application of M&S functions (whatever they are called by their developers).
- Finally, using intelligent software agents to continually observe the battle sphere, apply models and simulations to analyze what is going on, to monitor the execution of a plan, and to do all the tasks necessary to make the decision maker aware of what is going on, Command and Control systems can even support situational awareness, the level in the value chain traditionally limited to pure cognitive methods. With the application of software agents and the availability of necessary metadata, future SOA-based JC2 system will be able to support this level as well.

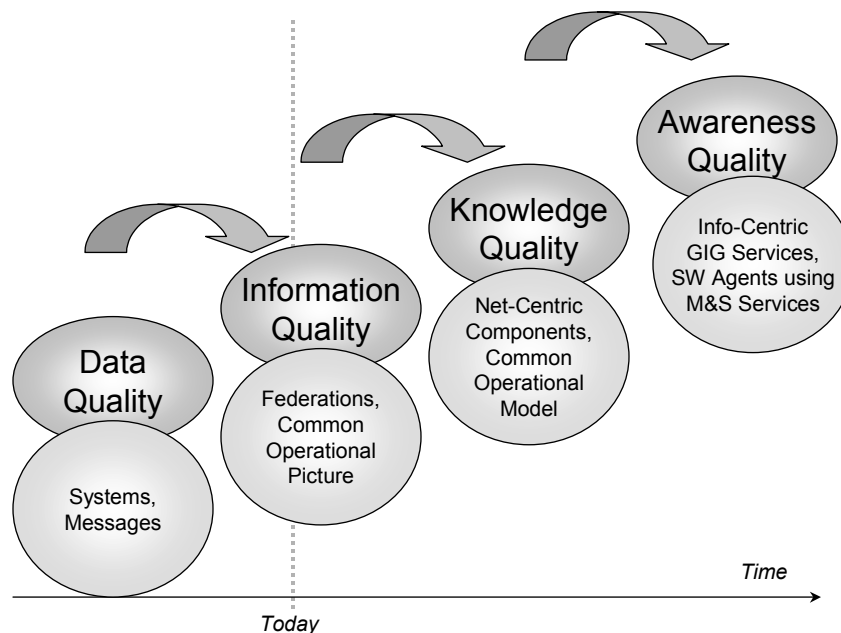


Figure 1: Command and Control Improvements [7]



The section motivated that operational M&S services are needed to support the warfighter in future JC2 systems like envisioned in the Global Information Grid (GIG). The following sections will cope with the technical requirements enabling this.

### ***Why do we need a Common Language in the GIG***

The actual trend within the US DoD is to “let the community evolve” towards standards. Mandating of standards has been replaced by the idea to use metadata standards enabling the mapping of information elements to each other in case of need using data mediation services. While the author supports the idea of reducing mandates where not necessary, a common understanding of the data to be exchanged is the fundament for interoperability. Although not sufficient, data interoperability is necessary for interoperability on higher levels, as depicted in figure 1. Without data interoperability, we will never reach information interoperability within the supporting IT systems. One of the most urgent problems that has to be solved before M&S services in service-oriented architectures can become reality is meaningful semantic data interoperability for information exchange between the services. While the Extensible Mark-up Language (XML) enables good solutions, XML alone is not sufficient. To cope with this challenge, the US DoD established the XML Repository, which is used to collect all relevant XML tag sets used within the responsibility of the US DoD. In addition to the DoD XML Registry, where XML tag sets are simply registered, the U.S. Department of Defense established the “DoD Metadata Registry and Clearinghouse.” The definition of the DoD Discovery Metadata Specification (DDMS) is a very important step towards data-driven net centric interoperability. The actual version of the DDMS provides basic summary content elements to capture content metadata. Activities are underway to test additional summary content elements that provide a more robust, structured method of describing the contents of a resource.

The real potential of SOAs lies in the possibility to compose services and to orchestrate their execution enabling new functionality compositions to fulfill the current often changing user requests “on the fly.” To this end, information must be exchangeable between all composed services. In order to do this in a meaningful manner, i.e., not simply exchanging bits and bytes but ensuring the interpretation of data in a consistent way leading to the same information, knowledge, and ultimately awareness within the services and their users, each service has to know what data is located where, the meaning of data and its context, and into what format the data have to be transformed to be used in respective services composed into a distributed application within the overall system. To generate the answers to these questions is the objective of data administration, data management, data alignment, and data transformation, which can be defined as the building blocks of a new role in the interoperability process: Data Engineering.

Data engineering is already a tremendous task when being used to couple two existing systems. The challenge becomes greater within an SOA. The developer of a service does not know who is going to use his service in the future. When he defines the data to be imported into his services and the data produced as a result, he cannot assume how this data will be used, under what constraints, etc. It is therefore necessary to avoid ambiguity. A common language is necessary to be used as a reference by all



participating players, including services and software agents. It is important to distinguish between the role of the reference model and the implemented solution. A common language does not imply that all services are using the same data model or the same implementation. They just use the same reference model to unambiguously define the meaning of their data.

In summary, a common language spoken by all participants is required. While the mandate for a common implementation is not recommended, the mandate for a common reference model for documentation and mediation is perceived as the necessary requirement for efficient and interoperable solutions by the author. The view is not a contradiction to but easily aligned with the current ideas on Net Centric Data Management. The only difference is to use a common language when defining the meta data constructs used in DDMS and similar constructs.

### ***C2IEDM as a Common Language in the GIG***

This leads to the question, which language should be spoken. The author recommends to use the Command and Control Information Exchange Data Model (C2IEDM). To understand this recommendation, a short overview of the history is necessary.

In 1978, NATO's Long-Term Defense Plan (LTDP) Task Force on C2 recommended that an analysis be undertaken to determine if the future tactical Automatic Data Processing (ADP) requirements of the Nations (including that of interoperability) could be obtained at a significantly reduced cost when compared with previous approaches. In early 1980, the then Deputy Supreme Allied Commander Europe initiated a study to investigate the possibilities of implementing the Task Force's recommendations. This resulted in the establishment of the Army Tactical Command and Control Information System (ATCCIS) Permanent Working Group (APWG) to deal with the challenge of the future Command and Control information systems of NATO. The ATCCIS approach was designed to be an overall concept for the future command and control systems of the participating nations. One constraint was that each nation could still build independent systems. To meet this requirement, ATCCIS defined a common kernel to facilitate common understanding of shared information, the so-called Generic Hub. In 1999, ATCCIS became a NATO standard with the new name Land Command and Control Information Exchange Data Model (LC2IEDM). In parallel to this, the project managers of the Army Command and Control Information Systems of Canada, France, Germany, Italy, the United Kingdom, and the United States of America established the Multilateral Interoperability Program (MIP) in April 1998. By 2002, the activities of LC2IEDM and MIP were very close, expertise was shared, and specifications and technology were almost common. The merger of ATCCIS and MIP was a natural and positive step. LC2IEDM became the data model of MIP. Finally, in 2003 the name was changed to Command and Control Information Exchange Data Model (C2IEDM).

There are two application domains for the C2IEDM within NATO: Data Management and Information Exchange. The NATO Data Administration Group used the C2IEDM to map all information exchange requirements between the national command and control systems to it in order to ensure semantic (What do the data mean?) and pragmatic (What are the data used for?) interoperability between the systems. The MIP data managers will continue this task after the merger between MIP and C2IEDM is finished. MIP also uses the C2IEDM to exchange data between national command and



control systems in order to foster sharing information and gain a common understanding on what is happening on the battlefield. To this end, the national systems establish data translation layers mapping their internal data presentation to the data elements of C2IEDM for information exchange with the other systems.<sup>1</sup>

Currently, C2IEDM comprises data elements describing a common vocabulary consisting of 176 information categories that include over 1500 content elements. C2IEDM is divided into a Generic Hub comprising the core of the data identified for exchange across multiple functional areas and special functional areas extending the Generic Hub under national responsibility to cope with information exchange needs of national concern. C2IEDM lays down a common approach to describe the information to be exchanged and is not limited to a special level of command, force category, etc. In general, C2IEDM describes all objects of interest on the battlefield, e.g., organizations, persons, equipment, facilities, geographic features, weather phenomena, and military control measures such as boundaries. Besides the technical maturity of this data model, the recommendation to use C2IEDM as the reference model for military information exchange is driven by the fact that all participating MIP nations already agreed that the information exchange captured in C2IEDM is operationally relevant and sufficient for allied operations. In other words: military and technical experts from 10 full member nations (Canada, Denmark, France, Germany, Italy, The Netherlands, Norway, Spain, The United Kingdom, and The United States) as well as 14 associate member nations agreed that C2IEDM is an adequate and operational meaningful way to exchange information about military operations, including new tasks like anti-terror operations. Speaking C2IEDM means speaking in operational terms to 14 nations in an accepted manner and in a NATO standard.

### ***XML based Data Mediation Services***

How can we use the C2IEDM as a common reference without implementing it? How can we make use of the data modeling expertise of hundreds of man-years without incorporating the model into the services? How can two services using different internal data representations be coupled and exchange information unambiguously without having to change their data model?

The answer to these questions lies within “XML Mediation Services utilizing Model Based Data Management.” In general, data management is planning, organizing and managing of data by defining and using rules, methods, tools and respective resources to identify, clarify, define and standardize the meaning of data as of their relations. This can be done individually or by using a reference data model to which all data elements are mapped to unambiguously define their meaning. Following the arguments given in the previous section, the author recommends to use the C2IEDM as this reference model for military services.

In the GIG, the translation of data formats used by the web services is handled by the mediation services, which belong to the enterprise wide applicable Net Centric Enterprise Services (NCES). Concerning these concept documents, mediation services will initially focus on the ability to transform between schema/document formats

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<sup>1</sup> As the mapping is done under national responsibility, the solutions may not be aligned sufficiently. XML based Data Mediation Services, as described in the following section, are the recommended alternative to such national data mapping and mediation solutions.



represented in XML, which supports the use of services discovered via the Discovery Service. Mediation Services will make use of service registries and metadata repositories to facilitate transformation of data interchange formats. However, it is not specified how this mapping will be organized to avoid another set of individual point-to-point mappings between services which cannot be reused by alternative solutions. The danger is that stove-piped systems, which cannot interact due to misaligned system definitions, are replaced with stove-piped services that, although running within a technically common infrastructure, are not aligned concerning their data information exchange definitions. “XML Mediation Services utilizing Model Based Data Management” bridges the gaps as follows:

- Every service defines its information exchange need using XML
- C2IEDM can be modelled using XML as well<sup>2</sup>
- Data management for XML based solutions equals tag set management
- Tag set management results in function-supported mapping structures from one tag set to the other.<sup>3</sup>
- These results can be used to configure the mediation services, which then can mutually translate the XML dialects into each other. In simple cases, this can be done using Extensible Stylesheet Language Transformation (XSLT).

Alternatively, each service can use its own mediation wrapper allowing him to speak and listen to C2IEDM on the GIG, but to use his efficient and application-specific data model internally. It should be pointed out that the data management and alignment work must be done for every two services to be composed anyhow, the recommendation is therefore to use common (meta-) standards from the beginning.

## **Summary**

Service-oriented architectures enabling the implementation of the Global Information Grid are evolving rapidly. Operational M&S services should be part of the architecture in order to support the warfighter with dynamic and agile services within all simulation application domains, ranging from training to real operations.

In order to make better use of the services delivering the necessary functionality, intelligent software agents are required. The agents need to make sense of the services functionality, their use of data, and their behavior. One of the most challenging tasks in this context is the management of information exchange requirements of services in a way that these services can be composed and orchestrated with other services during runtime delivering the functionality as specified by users during the ongoing operation.

The Command and Control Information Exchange Data Model (C2IEDM) is a matured approach for a military ontology in the domain of Command and Control. C2IEDM has been proven to be flexible enough to cope with all information exchange requirements of services. Technically, the definition of mediation layers to make this information available to services in general, including intelligent software agents, is

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<sup>2</sup> There are several alternative ways to derive an XML model from the C2IEDM data model. We recommend to use the method as developed by the Institute for Defense Analysis (IDA).

<sup>3</sup> This assumes that the tag sets belong to the same information domains, i.e., that they are aligned, and that they are of similar resolution, so that not too many aggregation functions are needed. The functions are needed to support simple operations, such as summing and subtracting. The ideal case is that only reversible functions are used, as this ensures that no information gets lost in the transformation.



feasible. XML can be used as a syntax layer, the C2IEDM definitions can be used for ensuring semantic interoperability, and the C2IEDM structures and views – which have been agreed to by military operators of the developing nations – can insure that the pragmatic view, i.e. how the data is used – is aligned as well. The results can be captured using XSLT and can be immediately applied for mediation service configuration.

By utilizing these technologies, military IT can support Joint Command and Control not only on the data and information level, but can increase knowledge and maybe even situation awareness.

### ***Related Publications of the Presenter***

These publications of the author are dealing with the same or similar topics in more academic depth. They also contain the references to relevant papers of contributors. All papers can be downloaded from the authors publication website at:

<http://www.odu.edu/engr/vmasc/TolkPublications.shtml>

- [1] J. Daly, A. Tolk. 2003. Modeling and Simulation Integration with Network-Centric Command and Control Architectures. Proceedings of the Fall Simulation Interoperability Workshop, Orlando, Florida
- [2] Tolk, Andreas. 2003. Common Data Administration, Data Management, and Data Alignment as a Necessary Requirement for Coupling C4ISR Systems and M&S. *Information and Security*, Volume 12, Number 2, pp. 164 – 174
- [3] J. Mark Pullen, Ryan Brunton, Donald P. Brutzman, David Drake, Michael R. Hieb, Katherine L. Morse, Andreas Tolk. 2004. Using Web Services to Integrate Heterogeneous Simulations in a Grid Environment. Springer Verlag, International Conference on Computational Science, pp. 835-847
- [4] Michael R. Hieb, J. Mark Pullen, William P. Sudnikovich, Andreas Tolk. 2004. Extensible Battle Management Language (XBML): A Methodology for Web Enabling Command and Control for Network Centric Warfare. Proceedings of the Command and Control Research and Technology Symposium (CCRTS), San Diego, CA
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- [6] Andreas Tolk, John J. Garcia. 2004. Model-based Data Management for Mediation Services for Intelligent Software Agents. Proceedings of the Symposium on Intelligent Software Systems for the New Infostructure, 16th International Conference on Systems Research, Informatics and Cybernetics (InterSymp-2004), Baden-Baden, Germany
- [7] Tolk, Andreas. 2004. An Agent-based Decision Support System Architecture for the Military Domain. Chapter 4 in Gloria Phillips-Wren and Lakhmi Jain (Eds.) *“Decision Support in Agent Mediated Environments,”* Sub-series Knowledge-Based Intelligent Engineering Systems, Sub-series of Frontiers in Artificial Intelligence and Applications, IOS Press B.V.
- [8] Tolk, Andreas. 2004. XML Mediation Services utilizing Model Based Data Management. Proceedings of the 2004 Winter Simulation Conference, International Society of Modelling & Simulation (SCS), Arlington, VA



# Battle Management Language - Enabling Semantic Interoperability

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Alion Science & Technology

ONR/CADRC Decision-Support Workshop  
Quantico, Virginia  
September 8, 2004



## What Is Battle Management Language (BML)?

- **BML is the unambiguous language used to:**
  - **Command and control forces and equipment conducting military operations and**
  - **To provide for situational awareness and a shared, common operational picture.**

A Military-Specific Domain Ontology

Along with this definition, we offer four principles that guide our discussion of BML though the paper:

- 1) BML must be unambiguous;
- 2) BML must not constrain the full expression of a commander's intent;
- 3) BML must use the existing C4I data representations when possible; and BML must allow all elements to communicate information pertaining to themselves, their mission and their environment in order to create situational awareness and a shared, common operational picture





## Four Principles of BML



- BML must be unambiguous
- BML must not constrain the full expression of a commander's intent.
- BML must be mapable to existing C4ISR data representations
- BML must allow all elements to communicate information to create shared awareness



## Do we have a BML?



- Battle Management Language currently exists.
- Soldiers use it every day to command and control live forces.
- Vocabulary defined by the doctrinal manuals...

(such as the Army's  
FM 1-02 Operational Terms)

- Associated grammar defined in other doctrinal manuals and from years of use.

- *Its focus*  
*is human – to – human*







## The Problem

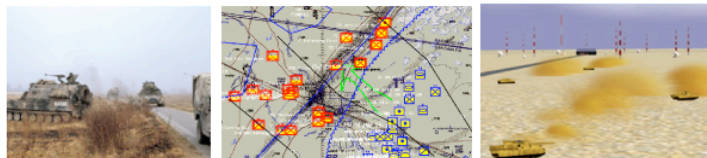
- Our current BML is a loosely knit “language” tailored to interpersonal communication.
- Its vocabulary is found in doctrinal manuals , but it lacks clearly delineated rules governing its use (semantics and syntax).
- It is riddled with ambiguity and overlapping definitions.
- As such, it is incapable of transitioning to the full range of automation desired by the DoD.



## The Problem (cont.)

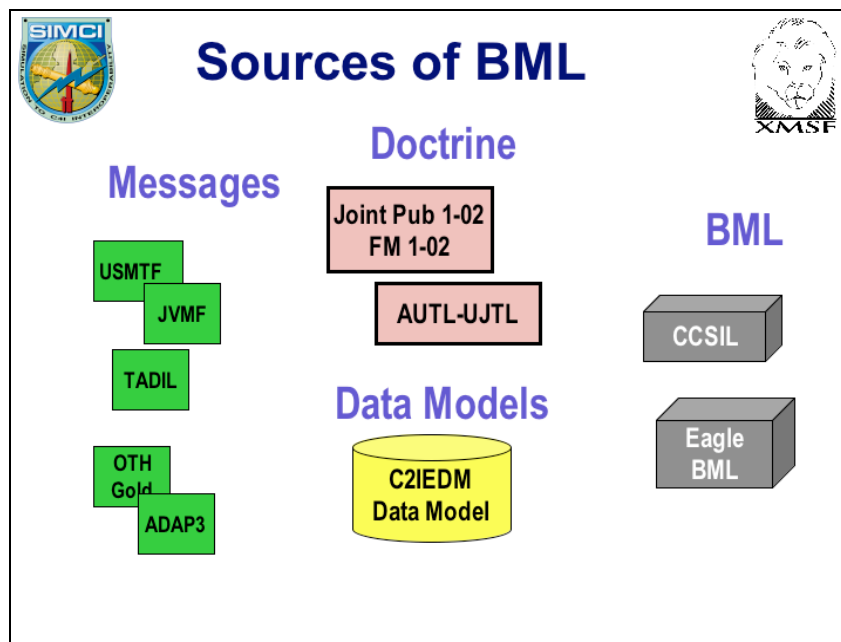
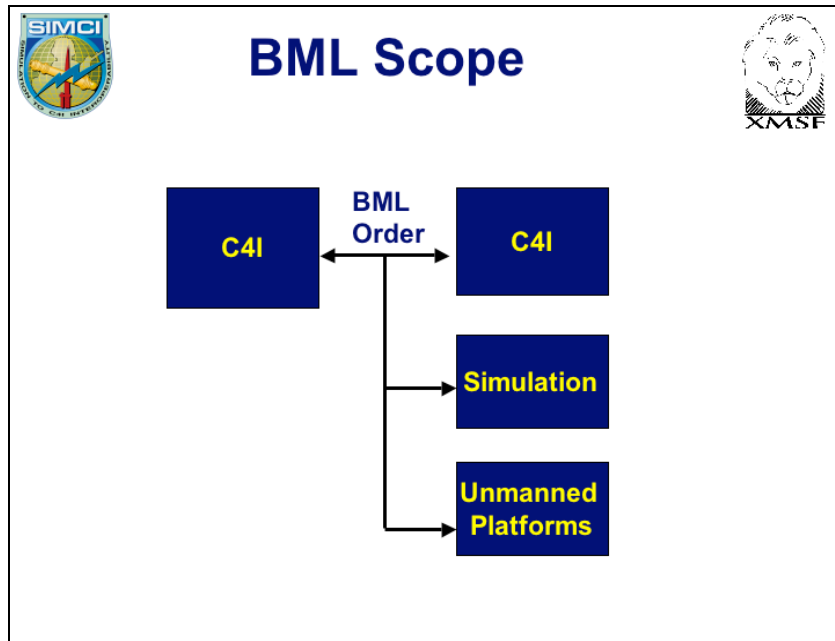
**If we are to train as we fight, then we must be able to communicate command and control information via the same C4I devices in all environments:**

- Live training and operations (soldier to soldier).
- Simulation training, mission rehearsal, and decision aids with the C4I devices stimulating and being stimulated by simulations. (Live, Constructive, Virtual simulation)



As emerging and future simulations are developed we are faced with three options in meeting the requirement for BML. First, we can continue as we have in the past and create BMLs that are specific to each simulation. Second, we can develop a BML that is standard within the simulation community and create interpreters between it and the C4I systems. Finally, we can develop a BML that is standard within both the simulation and C4I domains. To support the “train as we fight” principle, we recommend developing a BML that is standard within both domains.

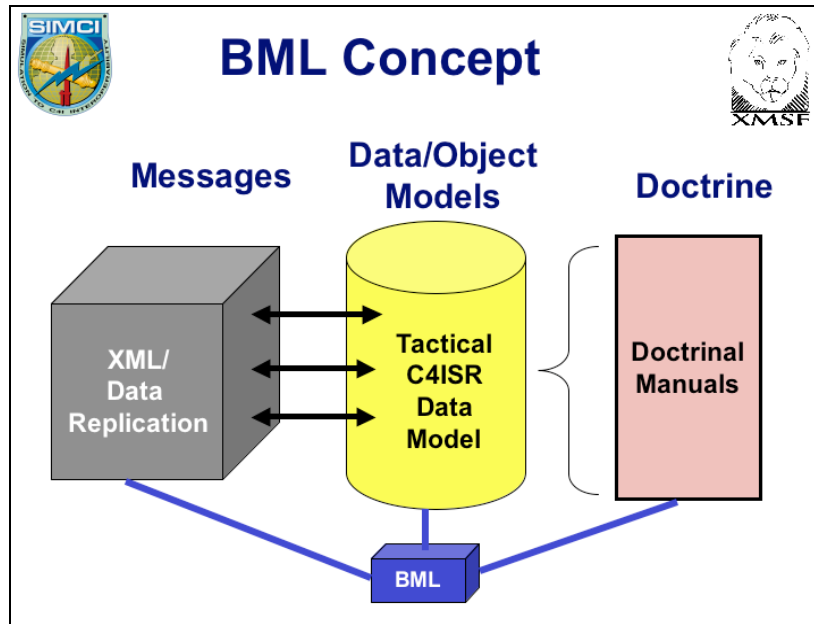




The next step in solving the problem is developing a concept for a BML. Figure 2 depicts the current state of disparate information, messages and languages.

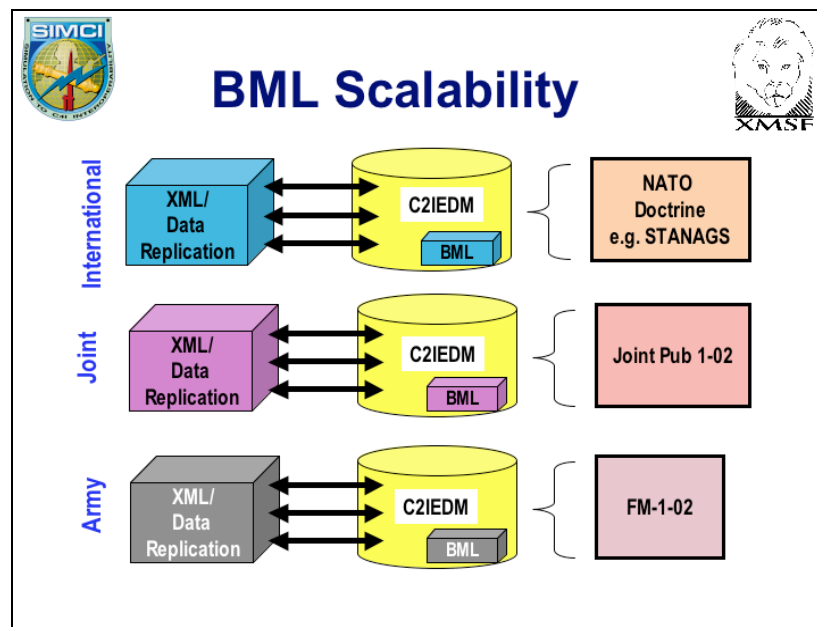
The sources of BML exist in the defined operational messages, the doctrinal manuals that define the vocabulary and provide insight to the semantics and syntax of the operational language, and the data base that contains the representation of the mission space. The past BMLs provide insight into ways to combine these sources to impose structure to the operational language and reducing the use free text.






Since the JCDB contains the representation of the mission space it is only natural to build the language used to communicate about the mission space into the same representation. This can be accomplished by ensuring the doctrinal terms and relationships that define the syntax and semantics are incorporated into existing and/or new data structures. Once this is accomplished communicating that information can be accomplished with a variety of means including data replication, XML, existing message formats, etc.

Linking the doctrinal base into the JCDB ensures that there is a clear mapping to support XML and other techniques and it also ensures that, as doctrine evolves to meet future challenges, the language remains current.








## Essence of Order Resides in the 5 Ws

1.2.3.4.5.

**Bravo Company attack hill 123 at 0630 hours to secure an over-watch position."**



**The 5 Ws**

**1. WHO:** which unit is to accomplish the task.

- Normally identified by a Unit ID.
- When Unit ID is in doubt, could be identified by location.
- Could be identified by ROLE (Main Effort, etc.)

**2. WHAT:** the task to be accomplished.

- Could be either an operation or ARTEP task.
- Selection maybe dependent on how much the higher commander wants to limit his subordinate. The more specific the task the less it conforms to "mission type".

**3. WHERE:** the location for accomplishing the task.

- Lat/Long, UTM, MGRS, etc.
- Terrain Feature ID,
- Graphic\_Control\_Measure\_ID


**5. WHY:** the reason for accomplishing the task.

- Purpose term. (Attrit, Defeat, Destroy, Contain, Clear, etc..)
- Parameters: (dependent on the term but required for clarification: Destroy what? Enemy Force, Terrain Feature)

**HOW:** In mission type orders, how to do a task is left up to the subordinate. The "general" how for the order itself is found in the context of the Commander's Intent and the Concept of Operations.


**4. WHEN:** the timing of the task.

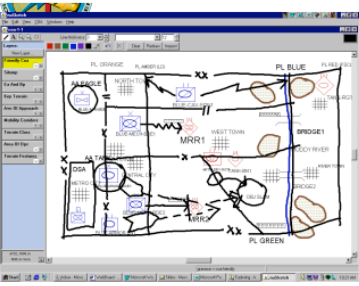
- Control type (AT a certain time, NLT a certain time, EVENT\_PLUS\_T (D+1, H+2, etc.)
- Parameters: (DTG, Event, Time, Unit\_ID, etc..)



## Course of Action Analysis Example

*Graphics convert to BML*





**Division Mission**

Division attacks on order in zone to seize OBJ SLAM.

**Division Concept of Operations**

Form of maneuver: Penetration  
Main effort: BLUE-MECH-BDE2,  
on order BLUE-ARMOR-BDE1  
Supporting effort: BLUE-MECH-BDE1  
BLUE-ARMOR-BN1

Deep: None  
Reserve: BLUE-AVN-BDE1  
Security: BLUE-CAV-SQN1  
Tactical Combat Force: BLUE-MECH-TM1

**Tasks to Subordinates**

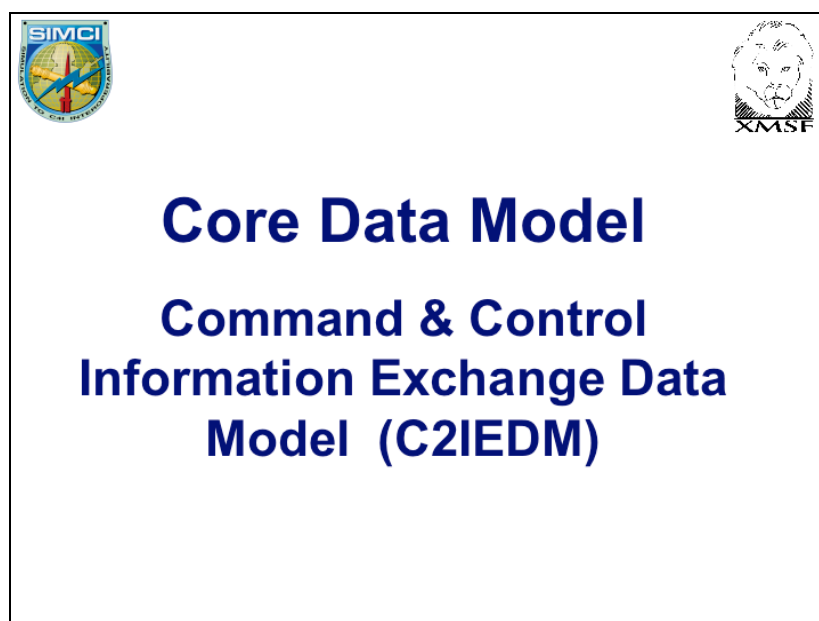
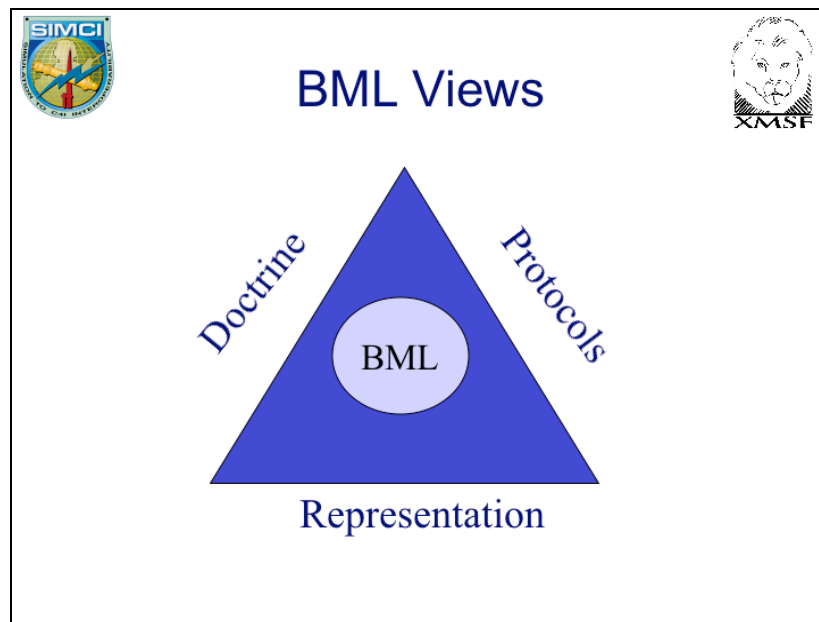
Who	What	When	Where	Why
BLUE-MECH-BDE1	Attacks	On order	Zone	Fix (MRR1)
BLUE-MECH-BDE2	Attacks	On order	Zone	Penetrate (MRR2)
BLUE-ARMOR-BDE1	Follows and Assumes (B-M-BDE2)	On order	Zone	Seize (OBJ SLAM)
BLUE-AVN-BDE	Occupy	On order	AA EAGLE	Reserve
BLUE-ARMOR-BN1	Follow and Support (B-A-BDE1)	On order	Zone	Support (B-A-BDE1)
BLUE-CAV-SQN1	Screen	On order	Zone (PL AMBER to PL BLUE)	Protect (Division left flank)
BLUE-MECH-TM1	Tactical Combat Force	On order	DSA	Protect (Division Rear Area)

This slide shows an example of a COA sketch. Imagine the graphics being linked to the BML. **1)** we can interpret the overall division mission: "Division attacks on order in zone to seize OBJ SLAM" Note that in place of the general description of Division we could actually identify the specific division by knowing what machine we were logged onto and keying to the ORG ID. Also "on order" was selected as the when for this example since there is not enough information to determine otherwise. Normally the COA sketch would be accompanied by additional products such as the COA statement and if analysis is complete, a synchronization matrix. **2)** we can determine the Division's concept of operation. Since this is an offensive operation we are interested in the chosen scheme of maneuver, in this case a penetration. We can identify the main



and supporting efforts as indicated. As well as the reserve, security and tactical combat force. Again without the additional products it is assumed that the Aviation Brigade is the reserve. It is also assumed that the Cavalry Squadron is performing a screen. The graphics shows it doing a security mission – by adding an S, a G, or a C to the graphic this would be clarified. **3)** we can translate the graphics into specific tasks to subordinates as shown. This could all be linked to the proper paragraphs of the OPOD and completed through auto-fill.

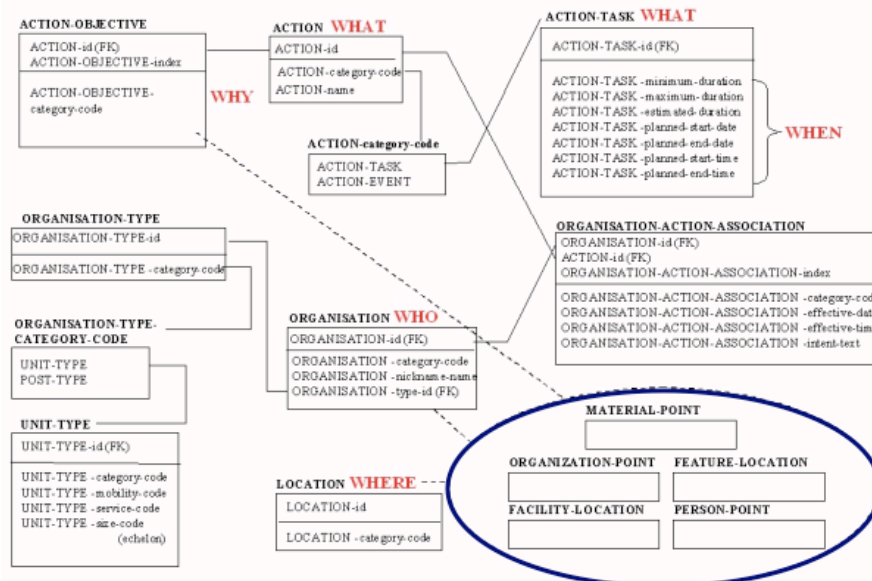
Though the simulation may only be able to interpret the message, we can see that it would be fairly easy to include graphics into the BML and translate the graphics to populate the correct fields of a BML message.



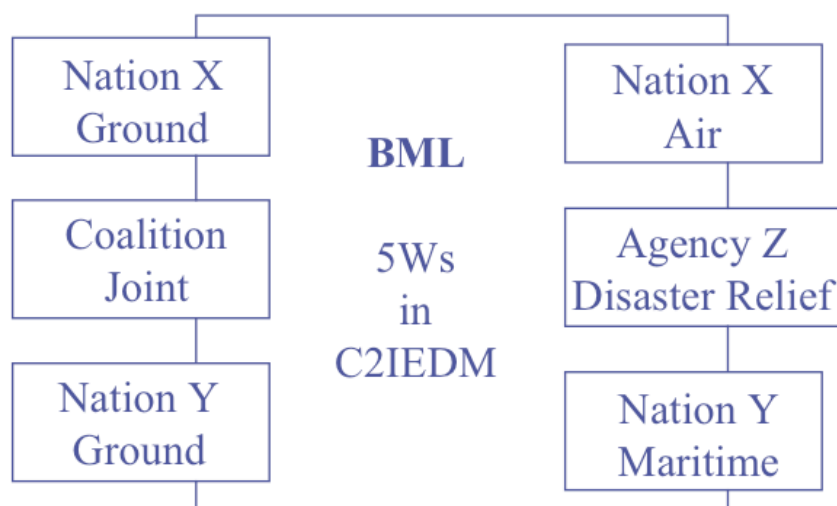




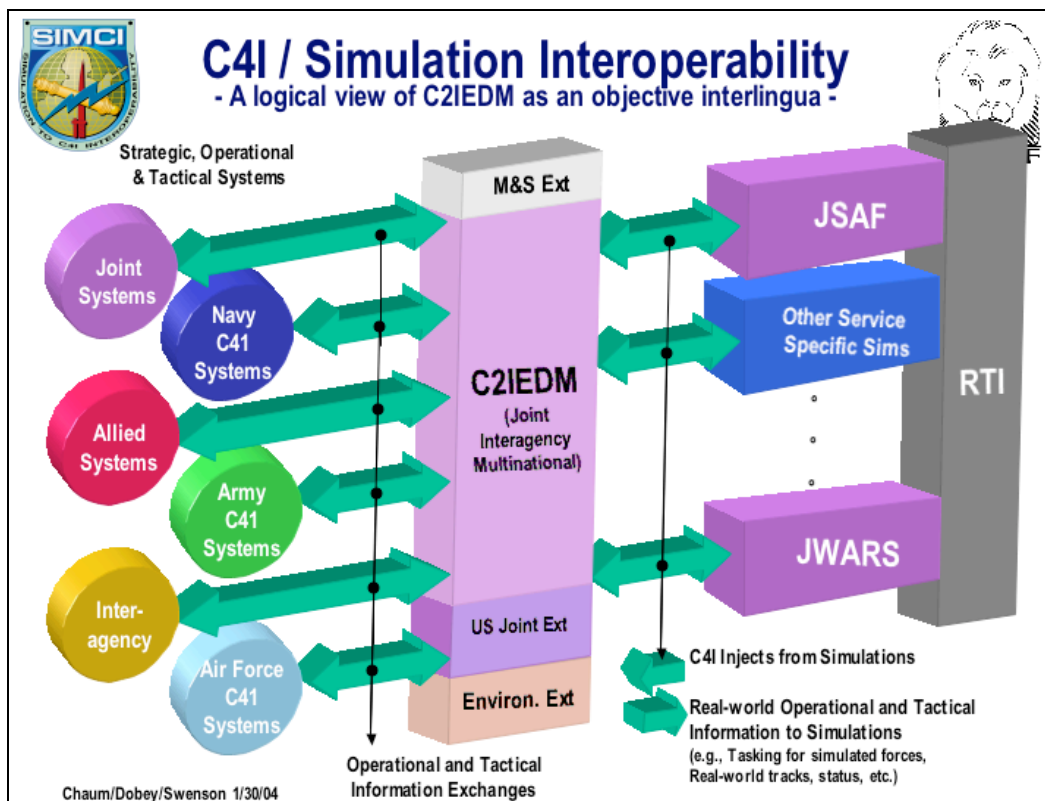
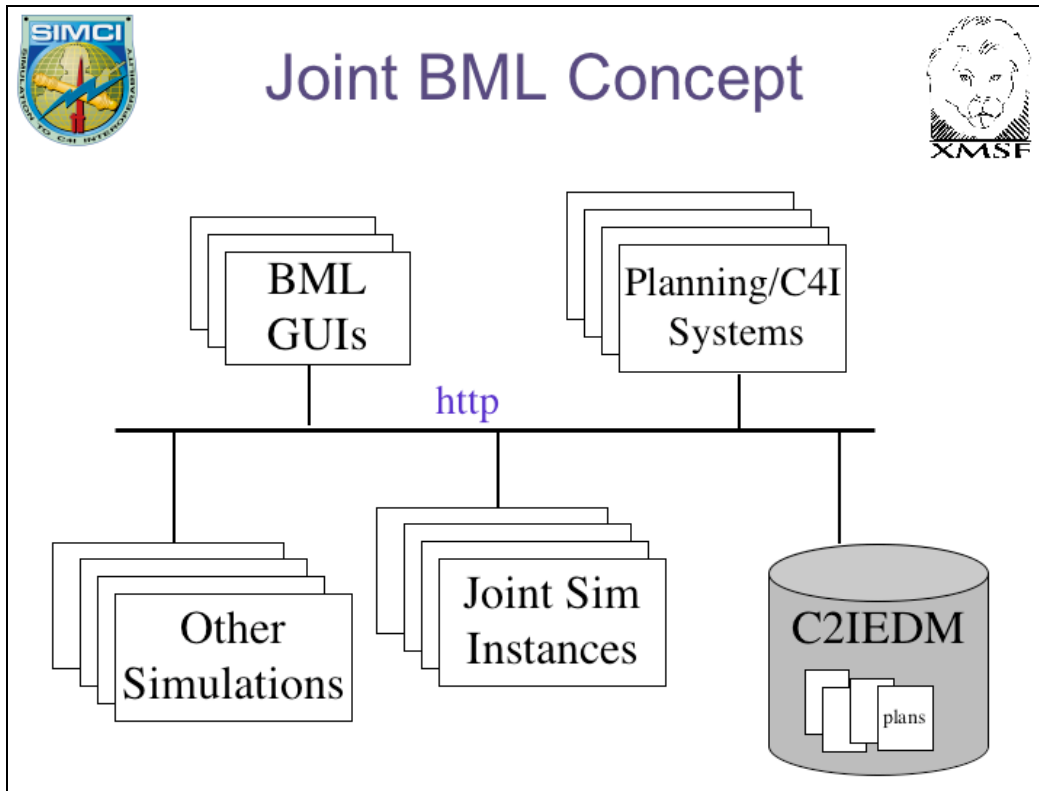
## Subset of C2IEDM Tables Showing the 5 Ws



## Coalition BML Implementation Concept: Extend the C2IEDM



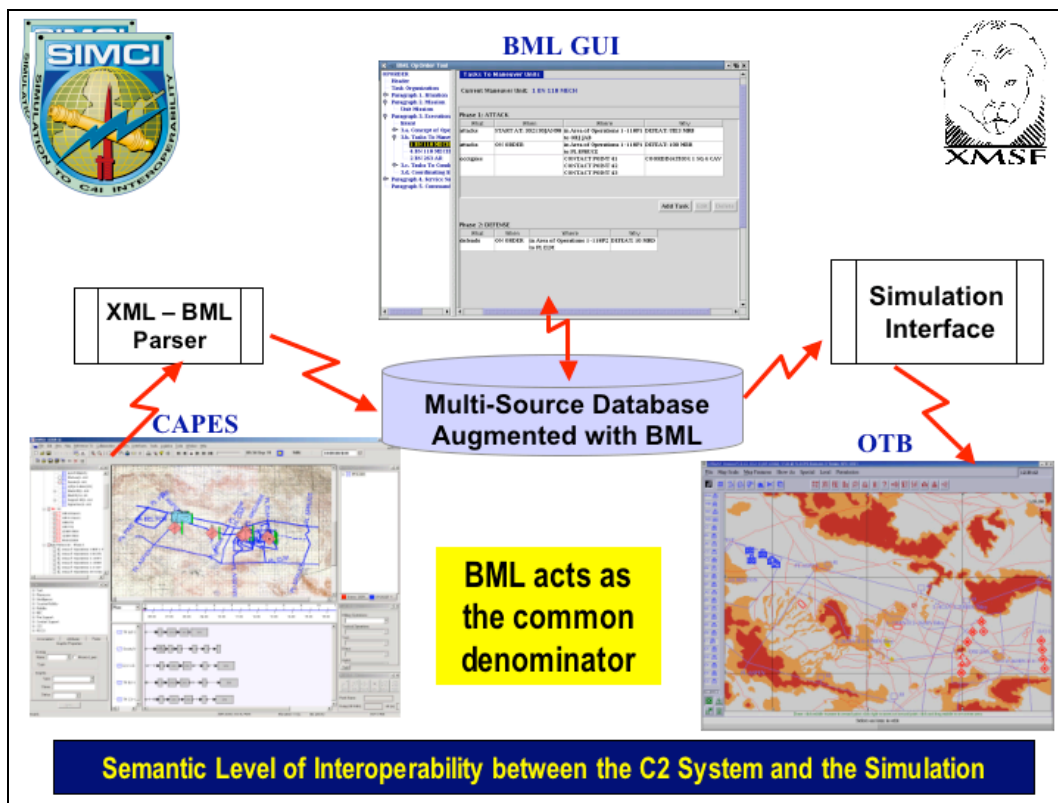




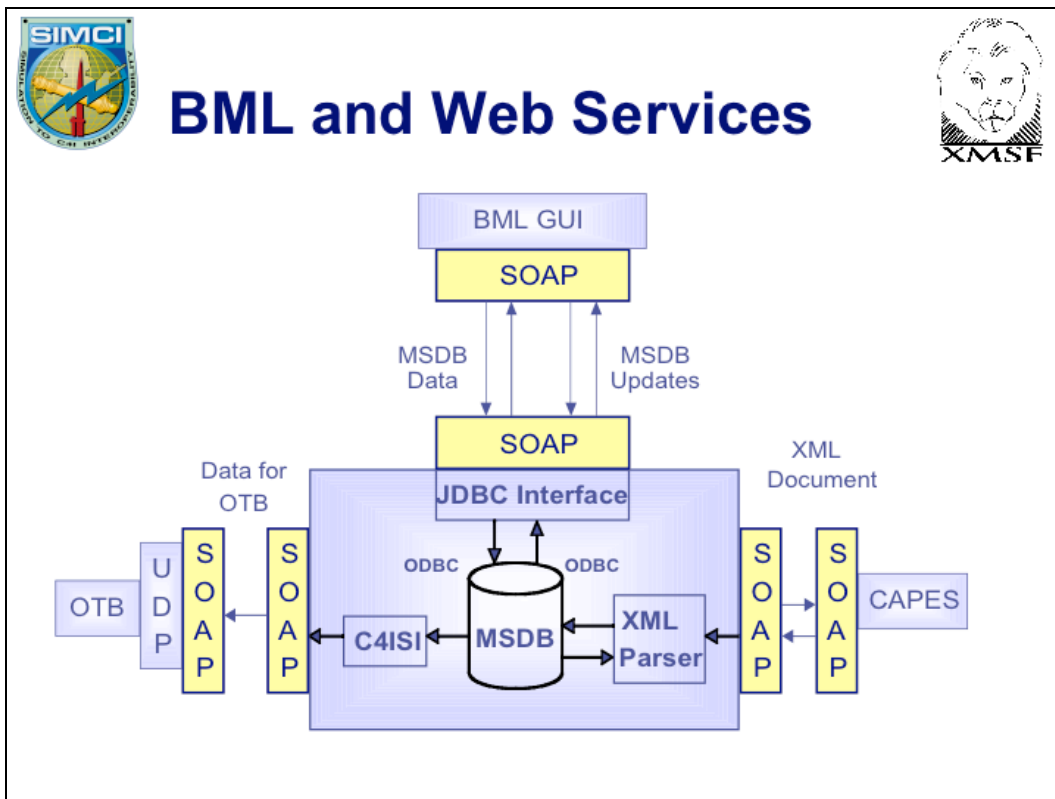
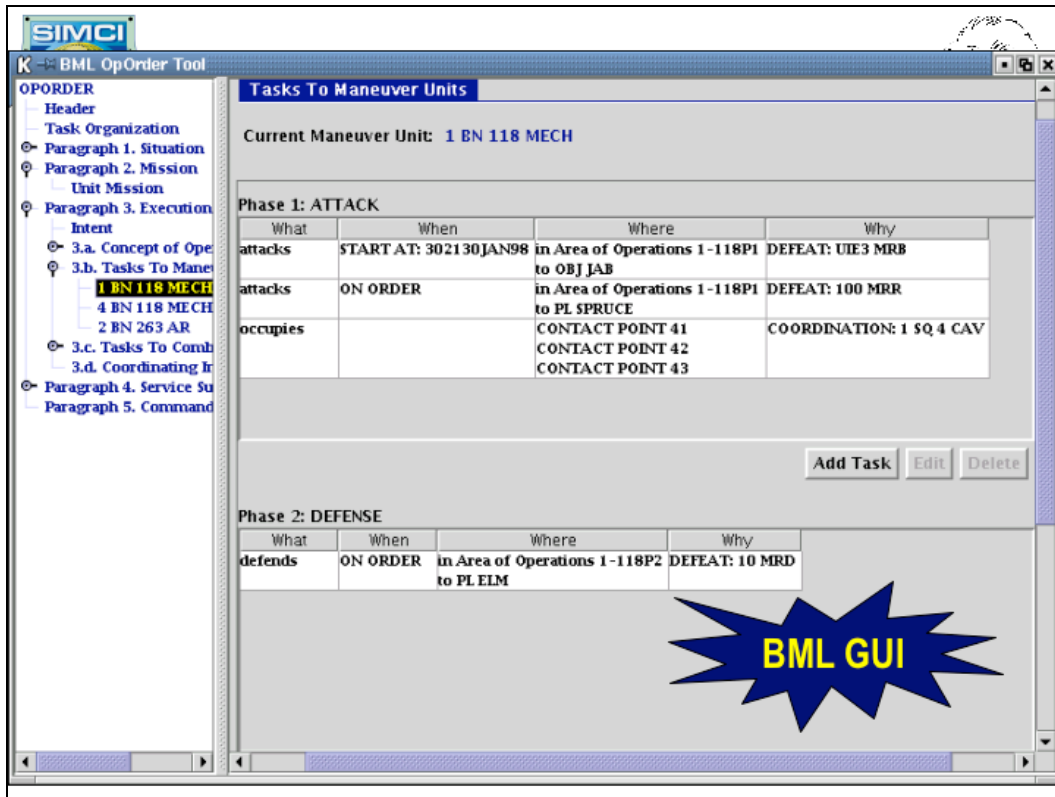




# Demonstrating BML











## BML Developments



- **Simulation Interoperability Standards Organization (SISO) Coalition BML Initiative**
  - United Kingdom
  - France
  - Germany
  - Strong Interest from other nations
- **Other Services**
  - Currently developing Air Tasking Order in BML
  - Working with JFCOM to demonstrate BML in large scale exercise



## BML as a Domain Ontology



Upper Level Ontology

BML as a Domain Ontology

C2IEDM as an Underlying Data Model





## Conclusion



### **BML Already Exists... But It's Too Loose**

- **Build a C2 Domain Ontology Based on Doctrine**
- **Establish Repositories & Metadata**

**BML Depends on Establishing a Core Data Model for C2**

**Use XMSF to Develop Joint/Coalition/Sims Interoperability**



## Questions?





## Acknowledgements



**Scott Carey** Northrup-Grumman

**Michael Hieb**, ALION Science & Technology

**Martin Kleiner** Northrup-Grumman

**Mark Pullen**, George Mason University

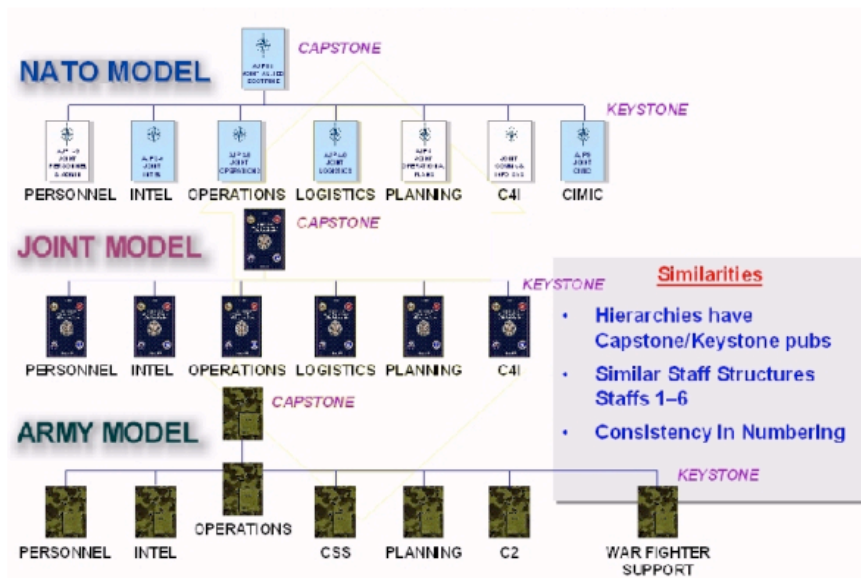
**William Sudnikovich** Atlantic Consulting Services

**Andreas Tolk**, Old Dominion University

**COL Ken Wilson**, Army Model and Simulation Office



## Army, Joint and NATO Doctrine Hierarchies





# Automating Decision Support for Architectures

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**Abstract:** This paper explores the use of decision support systems in the nontraditional role of analyzing architectures. We envision a scenario in which an analyst will need help determining the relationship between two portions of an architecture, and show how a decision support system might provide that help. The decision support system uses an ontology that is derived from the Core Architecture Data Model (CADM). We show how we derived the ontology from that model, then discuss how decision support can be embedded in the ontology and utilized by a tool. We present a detailed example to explain our work.

## 1 Introduction

This paper presents follow-on work to a paper given at the 2003 ONR/CADR Decision Support Workshop. That paper explored the use of ontology-based applications for automating decision support, with a special emphasis on command and control (C2) systems [IDA 2003]. The C2 emphasis reflected the data model underlying the ontology: the Generic Hub, version 5 (GH5) [NATO 2000]. This year's work continues to study the role of ontologies and knowledge bases in decision support, but uses architectural, rather than C2, data elements.

Decision support for C2 is of course a longstanding problem with a rich history, much of which predates computers. Architectures are, relatively speaking, a recent invention. Architectural standards are not so well evolved as C2 standards. Then too, architecture is a much larger domain than C2 (which is saying something). A C2 data set focuses on a particular operation, even if that operation happens to span an entire theatre of war. Architecture allows of all the concerns that go into the planning, procurement, and maintenance of a system, a family of systems, or a system of systems. Many subsidiary but important relationships exist among architectural data elements, adding further complexity to an architectural data model. Decision support for architectures, then, is more intricate and multifaceted than for C2. Concrete proof of this claim can be provided by noting the number of data elements in the data models we have studied: 833 in the C2 model, 4,128 in the architectural model.

This year's work also had technical concerns distinct from the underlying data model. The rule-based prototype system developed in 2003 implemented many of its rules as Java code. This approach, while acceptable in a prototype, has disadvantages in production systems. It forces analysts to express rules in a non-natural language: in a programming language, rather than in a domain-specific form. It makes certain changes (adding new rules, evolving existing rules) difficult, because implementing these changes requires extra programming, realignment of the user interfaces, new packaging, and configuration management of the deployed versions. A better approach is to implement the rules directly in the ontology, and preferably in a language designed specifically for that purpose. Rules are then easier to develop and modify, and are also centralized; packaging and distribution concerns are reduced. However, as we began our work the feasibility of developing realistic rule sets for the architecture domain was unknown, and so a goal of this year's project was primarily to determine feasibility.



This paper presents the results of this year's work on ontology-based decision support for architectures. Section 2 discusses the architecture data model used. Section 3 shows how this data model was converted to an ontology. Section 4 covers the automated decision support tools that make use of the ontology. Section 5 presents conclusions and directions.

## 2 The Core Architecture Data Model

The architecture data model chosen is the Core Architecture Data Model (CADM) [OSD 2003]. The CADM is designed to provide a common approach for organizing and portraying the structure of architecture information. Its data requirements are drawn from the 2,198 data requirements in the DoD Architecture Framework (DoDAF), version 1.0 [DoDAF 2003]. The CADM supports all of these requirements.

The CADM was primarily designed to be a logical rather than a physical data model. Its purpose is to define how architecture data is to be organized and related, not how it is to be stored. This said, however, the reader should be aware that physical schemas directly derived from the CADM logical specifications also exist, and that operational architecture data repositories have been built therewith.

Figure 1 shows an overview of the DoD Architecture Framework (DoDAF). It comprises three architectural views: operational, system, and technical. Each of these views is devoted to presenting, in graphical or textual form, selected facets of an architecture:

- The Operational View identifies those products that define participants, participant relationships, and participant information needs.

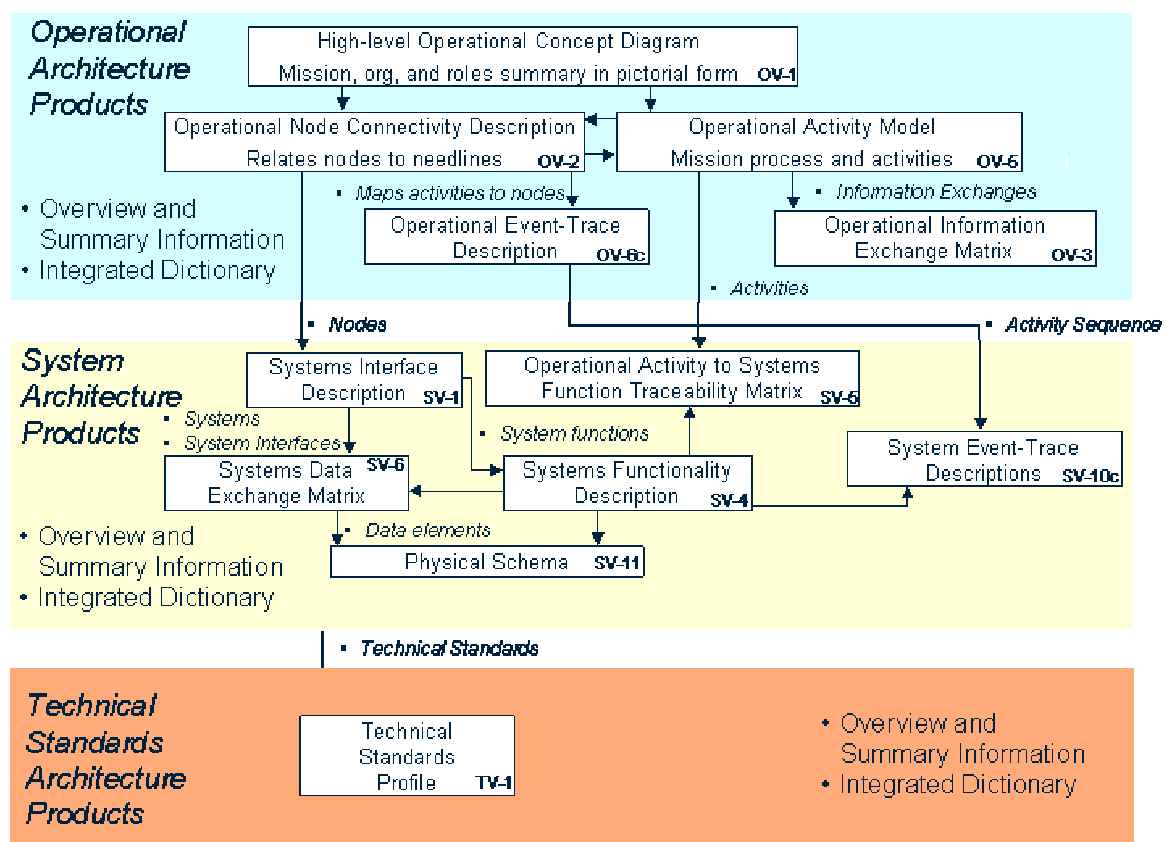


Figure 1. Overview of Selected DoDAF Architecture Products



- The System View shows how a set of one or more systems interact in support of DoD requirements identified in the Operational View.
- The Technical View specifies standards and conventions to which systems conform. These standards and conventions may derive from the Operational View, or they may be drawn from the System View when systems implement standards not otherwise prescribed.

Each view comprises multiple sub-views. For example, Figure 1 highlights five sub-views of the Operational domain. Each DoDAF architecture domain consists of some set of interrelated architecture products, and its products are related to other sub-views both as in and out of the overall Operational domain view.

The Operational, System and Technical views comprise the set of all possible architecture products that comprise any given DoDAF-conformant architecture. The topmost architecture product of the Operational View, OV-1, is a high-level operational concept diagram. Many architectural products, especially top-level ones, are diagrammatic and pictorial representations of information. The CADM establishes the data elements needed to make up such diagrams. For example, Figure 2 shows the key entities that make up a high-level operational concept diagram, and the relationships of these entities to other critical entities in the Operational View. Note that the “central” entity, CONCEPT-GRAPHIC {OV -1}, is a subtype of DOCUMENT. Many CADM products are ultimately represented as “documents”, in the general sense of the word. A document, in turn, has multiple associations, both with other documents as well as with the CADM entities that describe its contents.

- In CADM the relation of a given document to other documents is generally accomplished via DOCUMENT-ASSOCIATION, which defines relationships both within and without a DoDAF product. Figure 2 shows those associations for the OV-1 product within the Operational View.
- The relation of DOCUMENT to the MISSION entity in OV-1 (see Figure 2), provides context for how DoD requirements for a mission might be satisfied.
- The relation of DOCUMENT to the SYSTEM entity in OV-1 (in a many-to-many relationship via

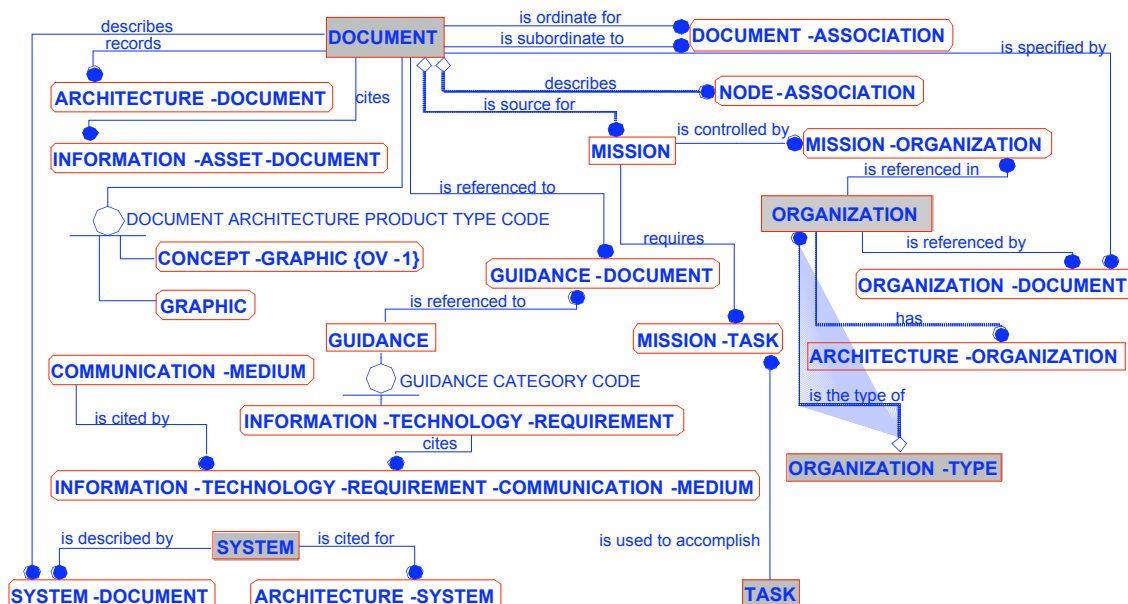


Figure 2. Selected OV-1 Entities



SYSTEM-DOCUMENT), describes the systems that play a role in a given high-level operational view. These systems can be either actual systems or, for a planned architecture, system candidates.

### 3 Deriving an Ontology from the CADM

The CADM is a logical data model written in the IDEF1X notation. It consists of entities, attributes, and relationships.

An ontology, by contract, includes a catalog of terms used in a domain, the rules governing how those terms can be combined to make valid statements about situations in that domain, and the "sanctioned inferences" that can be made when such statements are used in that domain. It is, therefore, designed with goals other than data storage in mind. The application of an ontology to decision support implies that an ontology-derived knowledge base must be more than an entity-attribute-relationship (ERA) model: it must support reasoning via rules about a data set.

There is, however, a great advantage in leveraging a pre-existing data model when developing an ontology, because any such data model is likely to contain valuable descriptions of the terms needed to describe the ontology domain. In addition, the population of a knowledge base is greatly facilitated if the catalog of terms used in the ontology closely track those of an implemented data store built in accordance with a data model.

It is for these reasons that the ontology developed for this project is based on the underlying CADM concepts. The ontology, however, extends them in multiple ways. This section describes the architecture ontology we built in this study and the design decisions that went into it.

#### 3.1 The Architecture Ontology Model

The architecture ontology was built using the Protégé knowledge base editor [Protégé]. This tool supports an OKBC [OKBC 1998] view of information, based on a *class* hierarchy. Each class has a set of *template slots*. A class can be instantiated; the resulting *instance* has an *own slot* based on each template slot. These **own slots** hold information about the instance. The nature of this information is determined by *facets* associated with template slots.

Classes and slots correspond roughly to entities and relationships in an ER model. Since an ERA model is a special case of an ER model, the OKBC model is at least as powerful as the ER model. In fact it is significantly more so.

#### 3.2 Mapping CADM Entities and Attributes to the Ontology

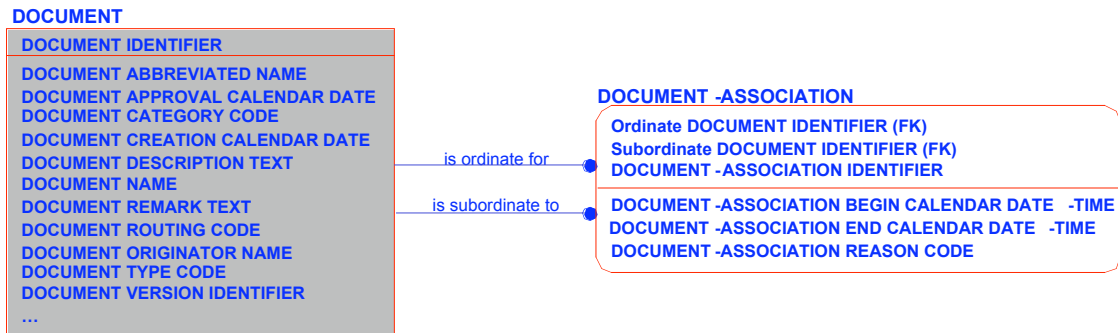
The fact that data model entities and attributes roughly map to classes and template slots suggests a straightforward translation of the CADM from a logical model into an ontology. We therefore adopted the following principles:

- Model each CADM entity as a class, and model subtypes as subclasses.
- Model each CADM attribute as a template slot.

Accordingly, the CADM ontology contains a class named DOCUMENT. This class has a template slot corresponding to each attribute in the CADM DOCUMENT entity.

This basic translation scheme works quite well with a few extensions. Protégé includes facets that can model the attribute specification elements of ERA standards such as IDEF1X [NIST 1993], including data type, minimum and maximum values, and default value. Protégé's predefined data types are not as rich as those in SQL definitions [ISO 2003] (and ERA models tend to use SQL definitions, given the expectation that a model will ultimately be represented as





**Figure 3. Two CADM Entities and their Attributes**

a database scheme); for example, a Protégé template slot can be specified as floating-point but not with precisions, such as NUMBER(9,7) (9 digits total, 7 after the decimal point, well suited to representing latitudes with precision down to one meter, but not for longitudes). However, the CADM-derived architecture ontology uses other Protégé features to model these facets of data types.

A one-to-many relationship in an ERA model is implemented using an attribute in the entity of which there can be many instances. In the ontology, the child class corresponding to that entity has a template slot that models the relationship. Automated reasoning applications usually require relationship information in the parent class as well. Protégé includes several OKBC concepts that support parent-to-child relationships:

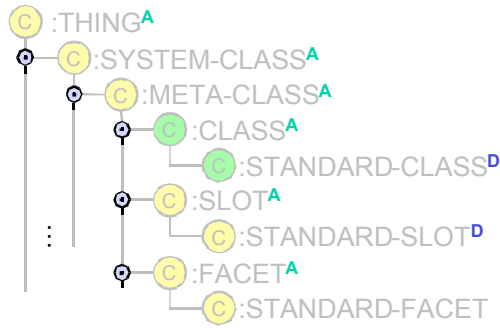
- A slot's range can be an instance of a class.
- A slot can have multiple values; that is, its value can be a set.
- A slot can have an inverse slot. A change to one automatically changes the other.

The CADM entities and attributes shown in Figure 3 are, therefore, translated into the following classes and template slots in the ontology:

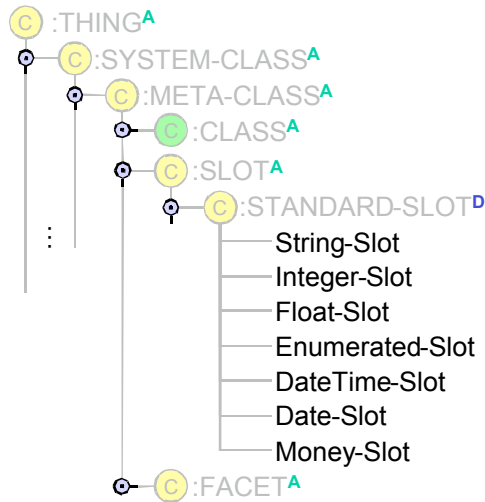
- Two classes DOCUMENT and DOCUMENT-ASSOCIATION.
- Template slots DOCUMENT ABBREVIATED NAME, DOCUMENT APPROVAL CALENDAR DATE, DOCUMENT CATEGORY CODE, etc. that represent values of organic attributes of the CADM entity DOCUMENT, and template slots DOCUMENT-ASSOCIATION BEGIN CALENDAR DATE-TIME, DOCUMENT-ASSOCIATION END CALENDAR DATE-TIME, and DOCUMENT-ASSOCIATION REASON CODE that represent organic attributes of the CADM entity DOCUMENT-ASSOCIATION. The logical names of the CADM attributes are used as names of template slots. The naming conventions used in CADM for entity attributes prefix each attribute with the name of their containing entity. We follow the same convention in our ontology, which has the added advantage of making all corresponding ontology slot names unique.
- Template slots DOCUMENT-is ordinate to-DOCUMENT-ASSOCIATION and DOCUMENT-is subordinate to-DOCUMENT-ASSOCIATION; these are associated with class DOCUMENT.
- Template slots inv-DOCUMENT-is ordinate to-DOCUMENT-ASSOCIATION and inv-DOCUMENT-is subordinate to-DOCUMENT-ASSOCIATION; these are associated with class DOCUMENT-ASSOCIATION and are inverse slots of the respective slots of DOCUMENT.

For our architecture ontology the CADM attributes that are part of keys and are not also foreign keys are not translated. In a knowledge base, every frame is automatically assigned a unique identifier when it is created. This identifier assumes the role of a key.





**Figure 4. Default Metaclass Structure in Protégé**



**Figure 5. Slot Metaclasses in CADM Ontology**

CADM foreign key attributes are translated into template slots in the architecture ontology, but with names that reflect the relationship in which they participate rather than the name of the attribute from which they derive. Thus Ordinate DOCUMENT IDENTIFIER exists in the ontology as *inv-DOCUMENT-is ordinate to-DOCUMENT-ASSOCIATION*. CADM complete subtype discriminator attributes are also unnecessary in the architecture ontology, as a subclass contains enough information to identify its parent.

### 3.3 Implementing Slot Semantics Using Metaclasses

The characteristics of the CADM that cannot be directly represented in Protégé can be implemented through *metaclasses*. A metaclass is a class that specifies semantics of classes, slots, and facets in the ontology. Protégé includes a special class *:SYSTEM-CLASS* that is the superclass of metaclasses. Protégé includes a standard set of metaclasses, shown in Figure 4. Ontology designers may add semantics to classes, slots, and facets by modifying or extending these metaclasses.

To represent CADM data types with more detail than Protégé normally allows, the CADM ontology extends the *:STANDARD-SLOT* metaclass with seven subclasses (Figure 5). These subclasses are based on the data type categories in the CADM. Each subclass has template slots that provide additional detail. For example, *String-Slot*

has template slots *String-Slot-Fixed-Length* (a Boolean) and *String-Slot-Maximum-Length* (a positive integer). All string-valued CADM attributes are represented in the CADM-derived architecture ontology as slots whose value type facet is string, but whose “type” – i.e., metaclass – is *String-Slot*. Length information in the CADM can therefore be associated with the slot.

Metaslots *DateTime-Slot*, *Date-Slot*, and *Money-Slot* do not add any template slots to *:STANDARD-SLOT*. They exist only to help characterize a slot’s role. This design decision is arguably redundant, because CADM attribute names include a description in their name (e.g., *DOCUMENT PUBLICATION CALENDAR DATE*, *DOCUMENT ASSOCIATION BEGIN CALENDAR DATE-TIME*). Our decision to allow this redundancy in the architecture ontology, however, was made for two reasons: first, to enforce a rule that all organic CADM attributes were translated to well-defined data types; and second, in anticipation of extensions that might facilitate reasoning.

Slots translated from code-valued attributes (those whose values are drawn from a fixed set of prespecified symbols) require special treatment. Protégé supports symbolic domains as a value type, and the CADM-derived architecture ontology does in fact use that feature to represent code-valued slots. However, at first glance the codes by themselves do not reflect sufficient semantic content to support reasoning. The majority are integer codes with no inherent relation to their domain, and the string values are often one- or two-character abbreviations. What semantics can be derived from a code is found in the code’s textual description.



The CADM-derived architecture ontology, therefore, incorporates code descriptions. The metaslot Enumerated-Slot includes a template slot Slot-Enumeration-Class. The value type of this slot, which is required, is a subclass of class Enumeration-Class. Enumeration-Class in turn has two abstract subclasses that are used to group the two kinds of enumerations in the CADM: strings and integers. Each subclass of these two classes models the set of codes: both code values and descriptions. Thus the symbolic value associated with the slot can be mapped to an instance of some Enumeration-Class subclass. Given this mapping, the textual description of a code is available for reasoning.

### 3.4 Representing Views

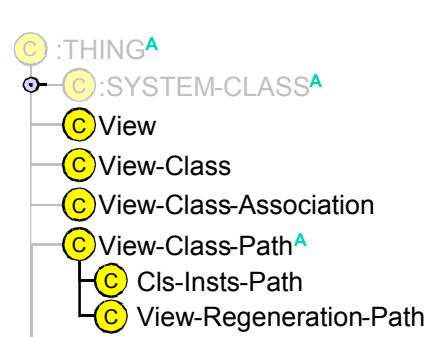
DoDAF users don't analyze every data element in the CADM. They concentrate on those elements necessary for the task at hand. The CADM has over two hundred views that assist in selecting elements relevant to areas such as requirements, operation, system analysis, user needs, and procurement.

The CADM ontology recognizes the importance of views and represents them using the six-class structure shown in Figure 6. A view is defined as an instance of class View. This class has three template slots:

- A string-valued slot defining the view's name.
- A multi-valued slot named `view-classes`, consisting of instances of View-Class; this (indirectly) defines the classes in the view.
- A single-valued slot that is one of the instances of the `view-classes` slot; this slot defines the "focus" class of the view. A view has a single class that can be identified as being central to the view, and that class is the value of this slot.

The View-Class class contains template slots that provide information about a specific class in the view, namely:

- A class that is one of those translated from an entity in the CADM. In the CADM-derived architecture ontology, these classes are all subclasses of CADM-Entity.
- Instances of View-Class-Association that denote parent-to-child (one-to-many) relationships of the referenced class.
- Instances of View-Class-Association that denote child-to-parent (many-to-one) relationships of the referenced class.
- The template slot of the reference class that provides a useful identifying string when displaying an instance of the class to a user.



**Figure 6. CADM Ontology  
Classes Supporting Views**

- Information on how to find instances of other classes in the view that derive from a given instance of the referenced class. This information is modeled as an instance of View-Class-Path; it is discussed in Section 4.

Class View-Class-Association models associations that exist between classes in the view. The aggregate set of associations can also be derived directly through examination of CADM entities. However, simply knowing the set does not provide enough context to discern certain association semantics. For example, class DOCUMENT has ordinate and subordinate associations with document-association. (see Figure 3). As another example, consider ORGANIZATION and ORGANIZATION-



HOLDING-MATERIAL-ITEM (see Figure 7). How should an inference engine distinguish between the two relationships between them: when is it appropriate to use is inventoried by and when is it appropriate to use provides? In our architecture ontology the View-Class-Association identifies one as the identifying relationship.

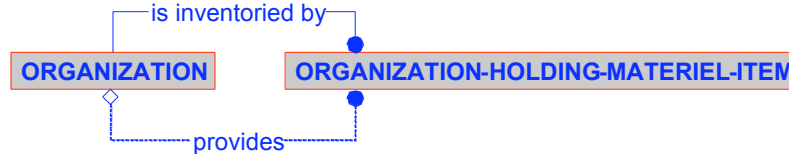


Figure 7. A CADM Entity with Multiple Parent-Child Relationships

## 4 Using the CADM Ontology in Decision Support

This section discusses how a decision support tool can use the CADM-derived architecture ontology. For our analysis we postulated that one of the purposes of a decision support tool would be to assist architecture developers in evaluating design decisions. Based on that assumption we have developed a prototype tool that enables the comparison of one architecture view to another. That is, given a populated CADM knowledge base, the prototype can be used to rank the degree to which instances in one view match instances in another view. An analyst could use the architecture ADS tool to help decide how well DoDAF architecture products of one type support the requirements of some other kind of architecture product.

More concretely, suppose an architect is analyzing requirements from an Operational View. For our scenario, let's assume that these requirements are specifically from an OV-5, which deals with activity model specifications. The architect wants to know what systems are available to help satisfy activity model requirements, and would also like help ordering the systems in terms of suitability to the activity model requirements at hand. Let's assume that this information is present in the DoDAF product SV-1 for that architecture.

Analysis of the CADM shows that there are relationships between activity models and systems. Given our approach in building the architecture ontology, similar relationships also exist in the prototype architecture ADS. In this scenario, we assume that these relationships have not yet been populated. Activity model needs have been described, and known systems have been categorized and populated in the architecture knowledge base, but no mapping has been made between the two. This is a fairly common situation in system design and implementation: functional experts may have worked out the operational requirements, while system engineers already have scoped the set of platforms available for implementation in a given timeframe. The role of the architect is to marry the two for an optimal solution. Hence, the questions the architect will have to answer, if he does not want to create a systems solution from scratch, are: What existing systems best satisfy the stated operational needs? And how are system suitability judgments to be made?

### 4.1 The Scenario Solution

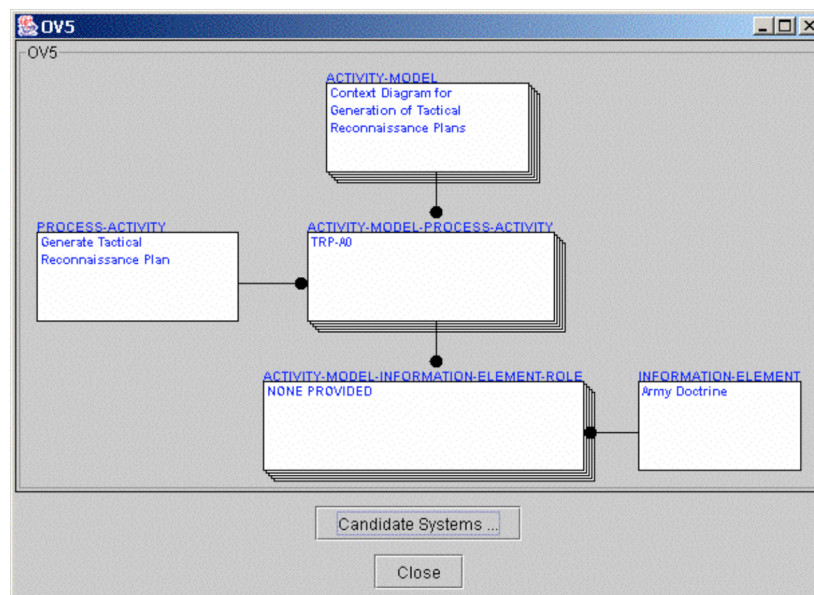
The following discussion shows how an architect would utilize the architecture ADS tool to solve the problem stated above. Subsequent sections discuss technical details of the tool.

We assume that the architect starts with a presentation of the OV5 view (Figure 8). This is a graphical depiction in the architecture ADS tool of the pertinent OV-5 instances; it has been condensed down to certain key entities for readability. It shows the activity model instances in



the knowledge base; one is shown (identified by textual label), and others are hinted at through the nested rectangles in the background. The architecture ADS tool graphic interface depicts the foreground activity model, which is related to many instances of Activity-Model-Process-Activity (AMPA), of which one (TRP-A0) is shown; this association of this instance with a single Process-Activity, and with multiple Activity-Model-Information-Element-Role (AMIER) instances are shown in turn. The tool graphical interface also shows that the foreground instance of the AMIER is related to an instance of Information-Element.

This window lets the architect select a specific set of OV-5 instances. Though it's not shown in this paper, he may select different instances than those in the foreground by double-clicking on a class. The architect is presented with the complete list of instances, and is allowed to select any of them. Associations to other instances are automatically changed: If he selects a different AMPA, the associated Process-Activity, AMIER, and Information-Element instances will change to those related to the selected AMPA.



**Figure 8. OV5 Window**

The architect's objective is to find candidate systems that satisfy the operational requirements encapsulated in the activity model(s) of the chosen operational view. He initiates this process by clicking the Candidate Systems button. This action pops up a criteria selection window (Figure 9). The criteria selection window helps the architect construct a query that addresses the candidate system selection problem. This query is based on comparisons of slot values between the two views. For example, OV-5 contains information on the estimated cost of an AMPA. It is reasonable to expect that an inference rule in the knowledge base could compare system cost to AMPA estimated cost, for example, to assess whether the budgeted funding for the process activity can cover the system(s) being analyzed as possible matches.

Even in these restricted views, many slot pairs are candidates for establishing the comparison criteria under which the suitability of a system for a given operational requirement is to be adjudicated. Because there may be so many pairing choices an architect likely will need help searching through them all. The prototype architecture ADS tool accomplishes this by grouping slot pairs based on data types. When the architect clicks one of the Details buttons on the right side of the window, he is presented with lists of slots from each view, and is given the

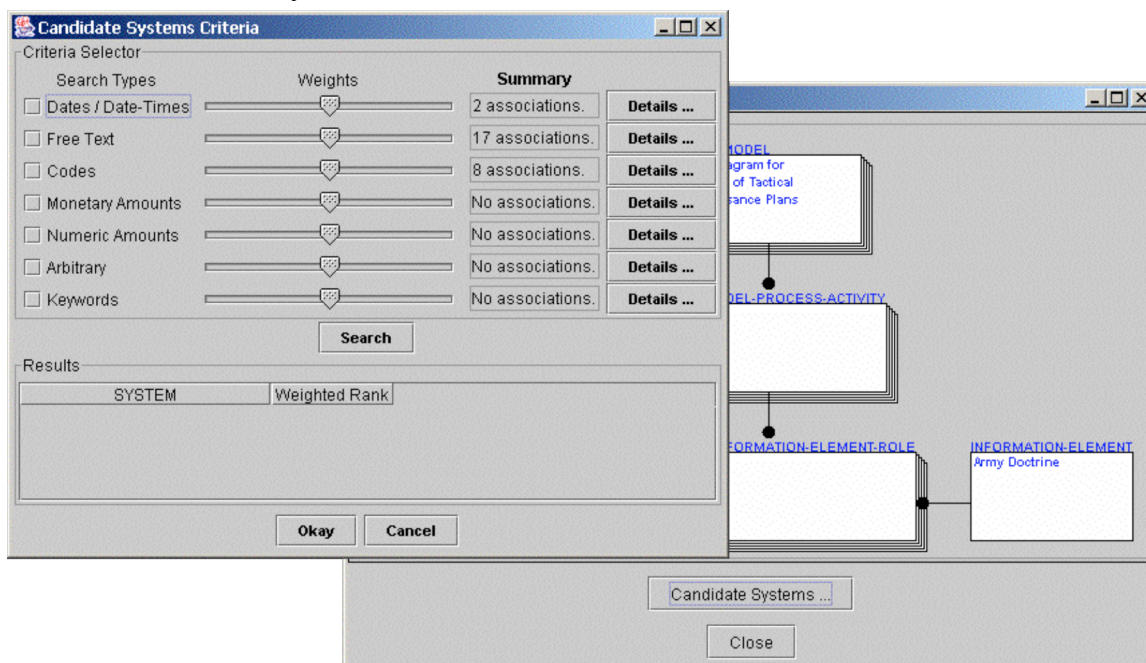


opportunity to include them in the comparison criteria. The architecture ADS tool aids the architect in this task by making some suggestions of its own. At present the logic for how the ADS tool generates these proposed pairings is based on a simple slot name string comparison. A more robust logic would be required in a full production-level implementation. The architect may include or remove any tool generated pre-selected pairs (Figure 10).

The architect has several choices for how to build the comparison operator. Our tests indicate, for example, that considering equality between text fields, especially free text fields, is seldom a fruitful comparison criterion. The three operators in Figure 10 include equality, but also containment (one field is a substring of the other) and matching. Matching is an information retrieval technique based on a vector space model [Frakes 1992]; it returns a numerical value between 0 and 1, inclusive, describing the degree to which one text-valued slot matches another. Matching is useful for the decision support tool because the user wants results ranked, not just yes/no answers.

Currently, the architecture ADS tool evaluations for how to match slots may not always be transparent from the user's point of view. If the architect is not satisfied with the choices given, he may match arbitrary slots using the "Arbitrary" line. Arbitrary slots may be compared using any operator that makes sense for the domain: equality, containment, and matching, and also inequality, less than, greater than, and operators of that ilk. The architect may also supply keywords (Figure 11). Keyword searches simply search for the presence of that text string.

Coded slots are treated specially. As noted, the descriptions of coded slots provide more information than the code values. Descriptions are used when searching for keywords or performing matching. However, equality and inequality are tested based on the code values. This heuristic seems most likely to be what an architect intends.



**Figure 9. Criteria Selection Window**

Once the architect has selected the criteria, he can click the Search button in the Criteria Selection window (Figure 9). The architecture ADS tool compares all SV-1 instances against the selected OV-5 instance set according to the criteria the user has established. It returns a ranked



ordering of systems, showing the degree to which they satisfy the criteria (See Figure 11). In this way the architect has gained knowledge of which systems are likely to satisfy the operational requirements encapsulated in the activity model(s) for that architecture.

## 4.2 The Decision Support Tool's Implementation

As mentioned in Section 1, one of the goals for this year's work was to embed inferencing rules in the ontologies rather than hard-wire them in code. This objective was the driving factor for the design of the architecture ADS tool.

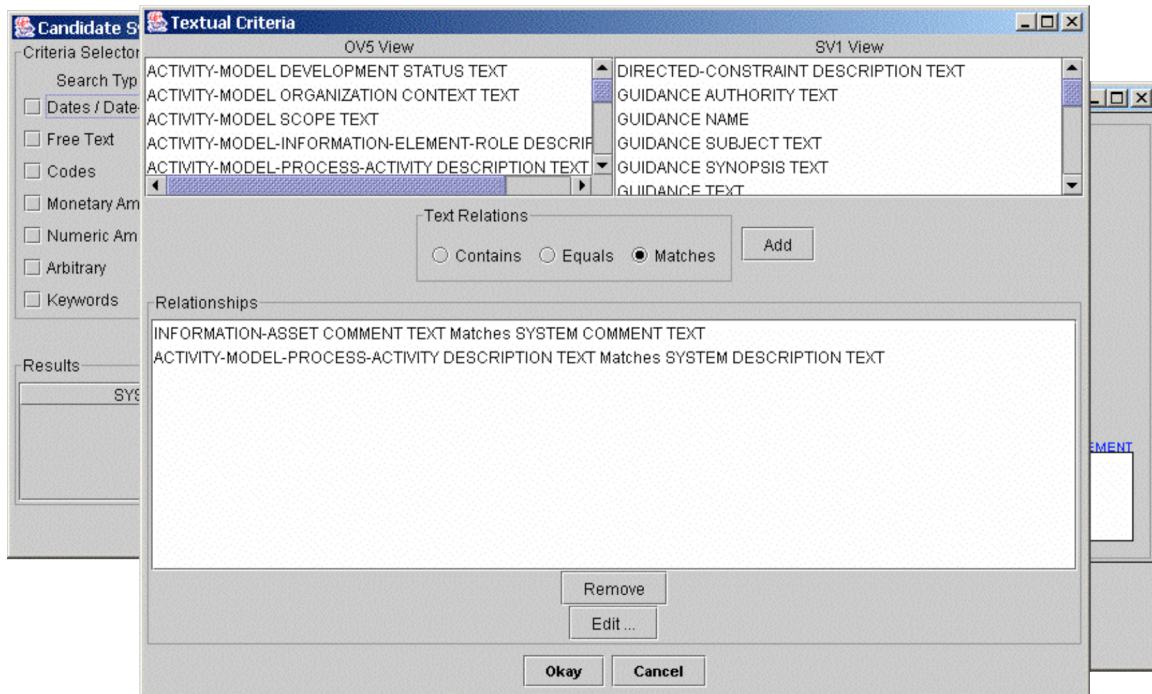
If the architecture ADS tool was to be rule-based, the next question was what rule processor to use. We examined several candidates and selected Algernon [Algernon]. Algernon was selected largely because of two factors. First, it is integrated with Protégé: a version has been rewritten specifically for use with Protégé, and has knowledge of Protégé classes. Second, it can invoke Java methods, a benefit that should not be underestimated. Other rule-based systems we investigated were self-contained and inextensible. While theoretically powerful enough, they lacked procedural and data abstraction capabilities, and their use would have required construction of enormously long and complex rules. Algernon's ability to invoke Java methods lets rule developers make use of Java's abstraction capabilities.

The decision support tool uses two types of Algernon rules. The first are instances of class Algernon-Path, a subclass of :THING, used to define self-contained paths, and its subclass Qualified-Algernon-Path. Instances of the latter class are permitted to have "qualifiers", which are variables that are substituted throughout a path prior to path execution. This is useful for, say, qualifying a path such that it applies only to a specific instance of some class rather than all instances thereof. For example, one prespecified rule is AMIER Instances derived from an AMPA, which, as its name implies, takes an AMPA as a qualifier and finds all AMIER instances related to that AMPA. Without the qualifier, the path would find all instances of all AMIERS related to all AMPA instances. This kind of rule, then, is used in regenerating information in the tool's graphical interface view windows (Figure 8).

Algernon also permits forward chaining: the ability to generate information based on discovery of information. A forward chaining rule was useful in generating the rankings, as discussed below.

The user queries that compare views are stated as Algernon paths. These paths cannot be prespecified in the CADM ontology, as the user causes them to be created dynamically. However, they can be formulated so as to use other paths, in particular the forward chaining rules.



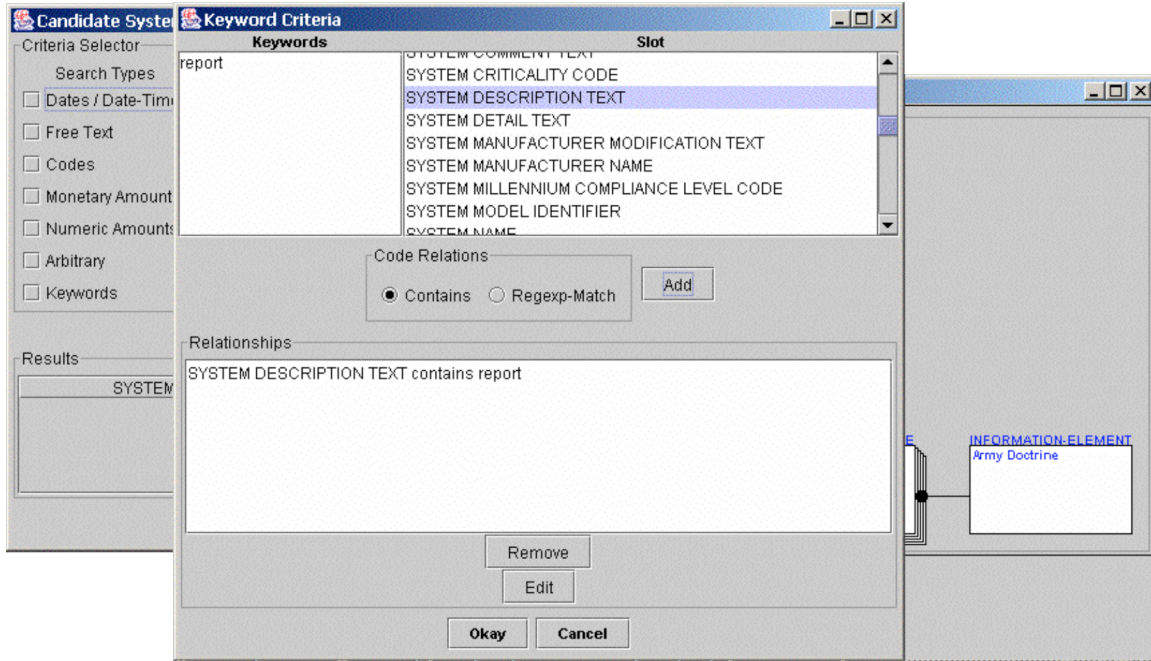


**Figure 10. Textual Criteria Specification Window**

In other words, when the architect clicks the Search button, the decision support tool examines the selections the user has made and converts these selections to an Algernon path. The path's purpose is to create information. Algernon causes this information to be expressed in terms of existing classes and slots. Therefore, it is necessary to extend the architecture ontology to model search results. Figure 13 shows the classes and template slots that model searches in the CADM ontology. Each distinct search is stored as an instance of class *Search*. A search focuses on obtaining results from a particular CADM class (in our scenario, *SYSTEM*); the results of a search are, therefore, a set of instances of that focus class. The CADM ontology models this as instances of *Focus-Cls-Inst-Rankings*, which has two template slots: one that denotes the focus class instance, and a second to record the rankings of that instance and how they were assigned. There is an instance of *Focus-Cls-Inst-Rankings* for each focus class found in the search (eighteen in Figure 12<sup>1</sup>).

<sup>1</sup> Actually, there are more: Only non-zero weighted rankings are displayed in search results.





**Figure 11. Keyword Criteria Window**

Each Ranking instance denotes a search category from Figure 9. The number of ranking instances is the number of categories the user has selected (three in Figure 12). A Ranking instance stores the overall ranking value for a category, plus the comparisons that category comprises. Each comparison is an instance of a Comparison-Description subclass, recording the relation used in the comparison and the numeric result of the comparison. Subclasses of Comparison-Description note the inputs to the comparison, supporting reproducibility.

The value slot of the Ranking class is the average of the values of the associated Comparison-Description instances. It is maintained by an Algernon forward chaining rule. Algernon automatically invokes this rule whenever an Algernon path causes a Comparison-Description to be associated with a Ranking. The rule re-computes the average and assigns it to the value slot.

The weighted ranks are not stored as part of the search. Weighted ranks are computed as the average of the search types, combined with a weighting factor. This weighting factor is user-controlled by a slider (see Figure 12). Since the weight is independent of the knowledge base, preserving it serves no purpose.

## 5 Conclusions and Observations

The extension of our work from C2 to DoDAF architectures has yielded some useful conclusions. We have succeeded in our objective to migrate rules from code to the ontology. Though not shown directly by the example in Section 4, the prototype architecture ADS tool can support the comparison of any two views, not just OV-5 activity models and SV-1 systems. The only changes required are to include definitions of the desired views in the CADM ontology, and to invoke the architecture ADS tool with parameters specifying these added views.



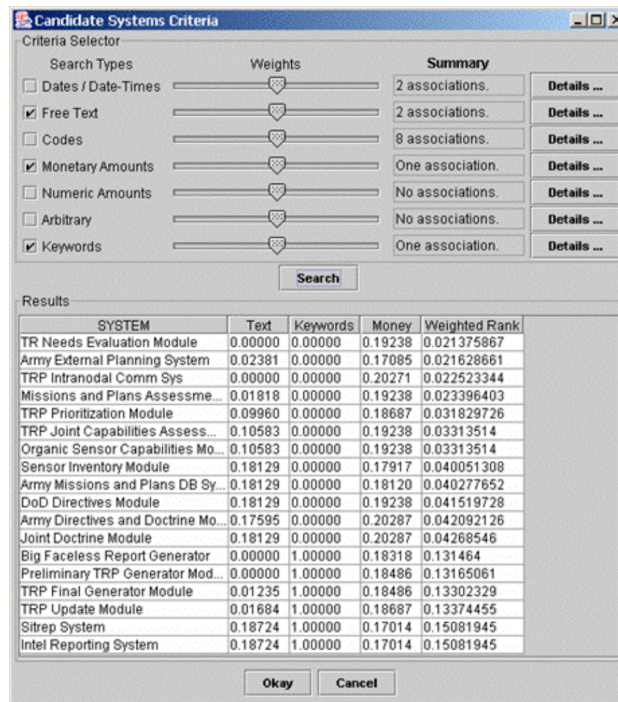


Figure 12. Search Results Window

The results obtained when executing searches with a populated architecture knowledge base appear to indicate that more work is needed in the formulation of criteria that depend mostly on the basic coded domains and textual entries that CADM allows. As shown in the rightmost column of Figure 12 the values one obtains using that approach are rather low, and, hence do not provide sufficient discriminatory power for a clear selection of a system in support of an operational requirement stated in the OV-5 view. The systems identified as best meeting the search criteria have a weighted ranking of only 0.15.

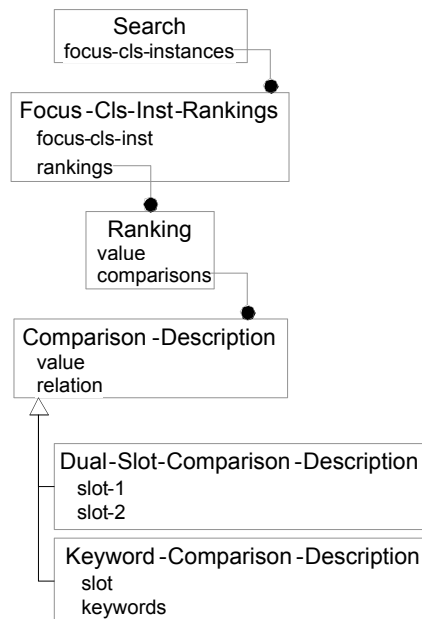


Figure 13. Ontology Classes Modeling Search Results



One possible cause of this problem is that the knowledge base was populated with a notional data set rather than real architecture examples. The elements of that data may not necessarily be representative of the diversity one might expect from real project data. Then too, the use of text matching via the vector space model adopted may be inherently inadequate in the absence of a more formalistic way of creating the description texts for systems. This may indicate the need for adopting text templates with well-defined key-words that all architects could use. Such an architecting process addition would improve the results and justify the use of the vector space model, which otherwise is very attractive due of its ease of implementation. It is quite likely that better algorithms would improve the diversity and magnitude of the numeric values assigned to the rankings, so that an architect could use them for formulating his systems selection. We expect that further study of real data sets will help resolve this issue.

## References

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# XML-based C2IEDM Interchange and XML Tactical Chat (XTC) for Global Interoperability

Don Brutzman

Naval Postgraduate School (NPS)  
Center for Autonomous Underwater Vehicle (AUV) Research  
Modeling, Virtual Environments & Simulation (MOVES) Institute

9 September 2004

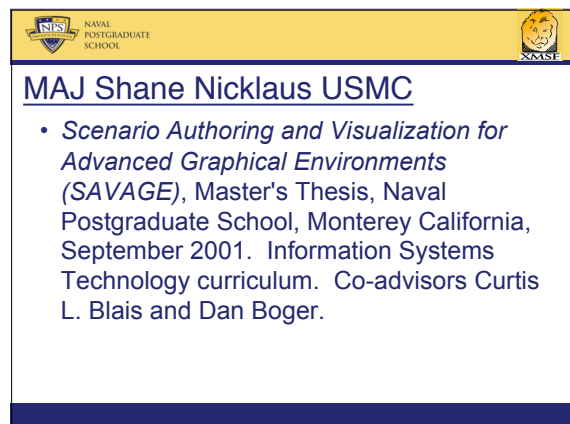
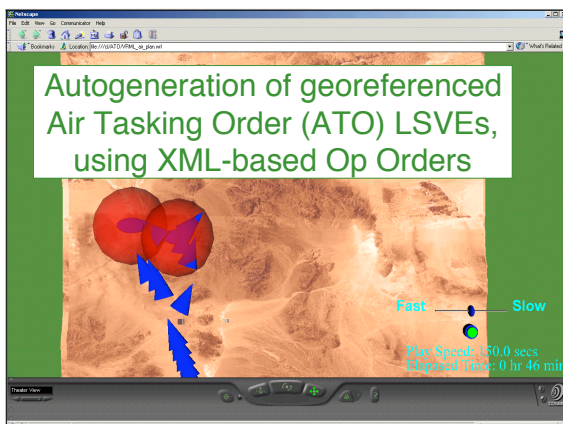
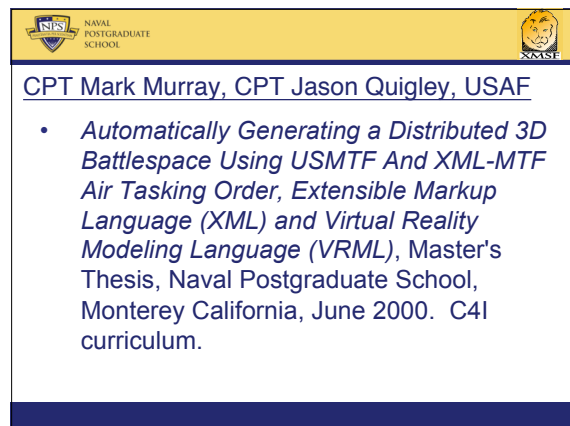
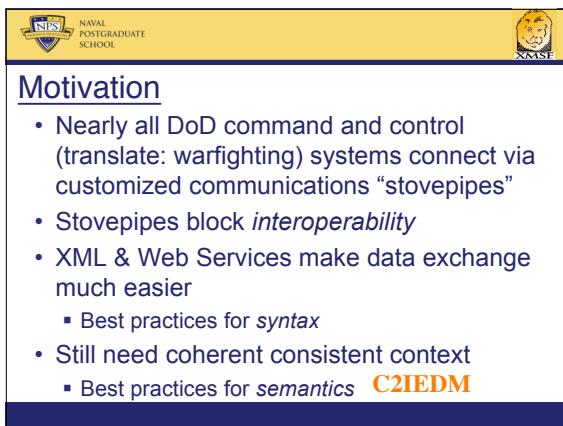
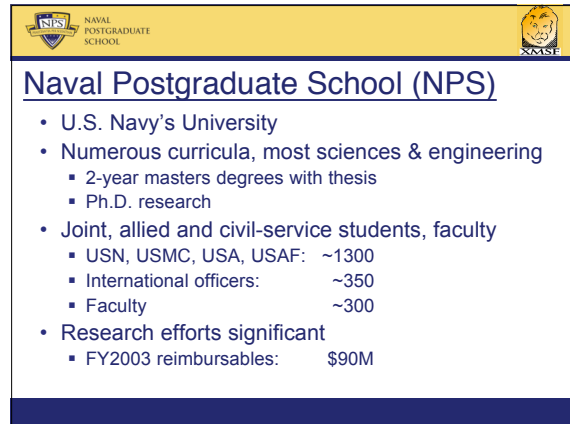
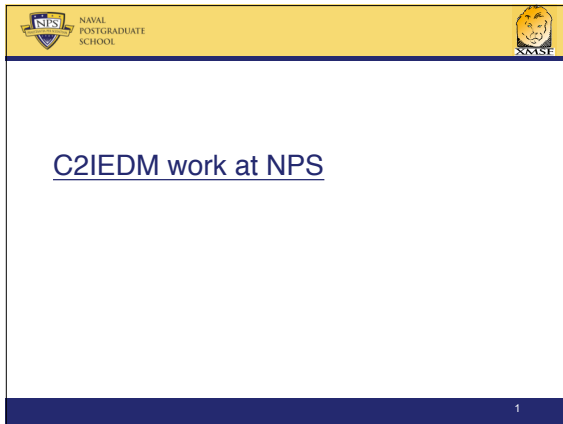
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## Topics

- C2IEDM work at NPS
- Technologies: XMSF, X3D, XSBC
- XML Tactical Chat (XTC)
- Exemplar: NPS AUV Workbench
- Lessons learned, conclusions and recommendations









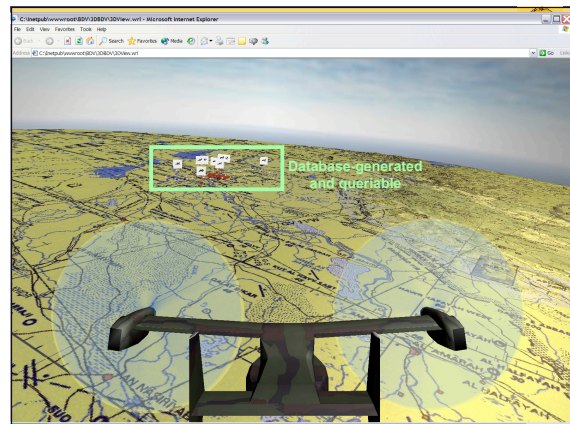






## MAJ Claude Hutton USMC

- Hutton, Claude O., *3D Battlespace Visualization using Operational Planning Data*, Master's Thesis, Naval Postgraduate School, Monterey California, September 2003. Co-advisor Curtis Blais.
- Integrates multiple intelligence-related sources, uses database/XML queries to autogenerate Baghdad
- <http://theses.nps.navy.mil>



## Glenn Hodges, MAJ USA

- Map tagset for Unit Order of Battle (UOB) to C2IEDM
- Provide database-centric XML Schema for C2IEDM v6.0
- Thesis available OCT 2004



## Transformation of Modeling and Simulation: Meeting the New Analytical Agenda

**Sponsor:** OPNAV N81  
**PI's:** Don Brutzman, Arnie Buss, Curt Blais  
**Goal:** Multiple coordinated world-class modeling projects to advance the new DoD analytical agenda. Web-compatible framework of open standards + open source for analysis by extending legacy model interoperability, composability.  
**Technologies:** Hybrid of Naval Simulation System (NSS), U.S. Army Combat XXI simulation system linked via SimKit discrete event simulation and Web Services messaging.



**Tasking and Deliverables (6 total projects)**  
**Analytical Modeling Framework:** Establish software framework of composable, scalable analytical models via XMSF Web Services  
**Analytical Workbench:** Capture, consolidate prior SimKit models by NPS students and faculty into a powerful analytical toolkit  
**Analyses:** Perform analyses of interest to N81 using the extended hybrid modeling capabilities of NSS/Combat XXI, including:  
 - Joint Forcible Entry Options, and  
 - Improved Strike Module  
**Force Protection/Anti-Terrorism Modeling:** Enhance FPIAT tool, combine 3D visualization, port defense rehearsal, tactical analysis  
**Special Operations Forces (SOF) Modeling:** ship-to-shore and then return, visualized using SAVAGE X3D Model Archive  
**Advanced Methodology:** extend/connect model hierarchies  
**Diverse Approaches:** multiple Operations Research (OR) theses  
**Logistics:** integrated theatre logistics M&S (under consideration)

**DoD/DoN Impact**  
 We're showing how to create an open marketplace of ideas, rather than products, connecting multiple models together

**NPS Involvement**  
 • Several dozen student theses led up this project  
 • 15 faculty (MOVES, OR) are participating  
 • 6 staff for software development, analysis

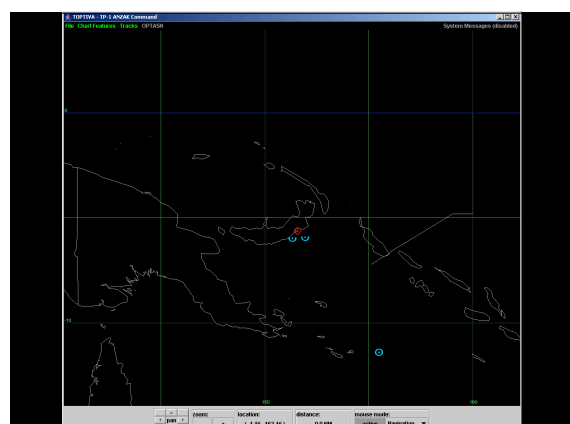
**Milestones**  
 • MORS Symposium, Monterey June 2004  
 • OPNAV presentations, September 2004

**Partners**  
 • Rolands + Associates Inc., Metron Inc.  
 • USMC MCCDC, USA TRAC White Sands & Monterey  
 • XMSF efforts include DMSO and additional partners

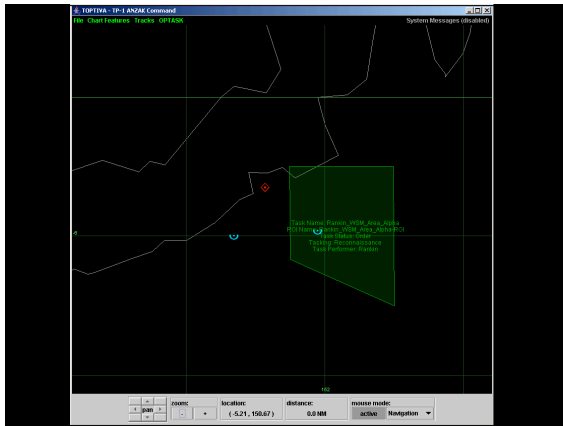



## NUWC work: TOPTIVA

- TASWC OPTASK Interactive Viewing Application (TOPTIVA)
- Fred Burkeley, NUWC Newport RI
- C2 application for Multilateral Interoperability Programme (MIP) C2IEDM
  - presentation of track and unit position reports
  - generation, sharing, and presentation of operational tasking orders
- Java, OpenMap interface, C2IEDM v6.0 XML, database







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## XML Messaging **Key to systems interoperability**

- Fixing message interchange can be outside the code boundaries of legacy systems
  - XML converters on stovepipes filter input/output
  - Avoids rewriting legacy software
  - Provides syntactic and semantic interoperability
- Insist on human readability/fixability
- Beware XML-MTF problems
  - Preserving backwards compatibility at the expense of cross-domain interoperability

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## XML-based Enabling Technologies

XMSF, X3D, XSBC

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## XML in 10 Points

<http://www.w3.org/XML/1999/XML-in-10-points>

- XML is for structuring data
- XML looks a bit like HTML
- XML is text, but isn't meant to be read
- XML is verbose by design
- XML is a family of technologies
- XML is new, but not that new
- XML leads HTML to XHTML
- XML is modular
- XML is basis for RDF and the Semantic Web
- XML is license-free, platform-independent and well-supported

400+ member companies & institutions in World Wide Web Consortium (W3C) already understand the business case

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## Extensible Modeling & Simulation Framework (XMSF)

- Web services for all manner of M&S
- A composable set of standards, profiles, and recommended practices for web-based M&S
- Foundational precepts: Internet network technologies, Extensible Markup Language (XML)-based languages, and service-oriented architectures for simple messaging
- Enable a new generation of distributed M&S applications to emerge, develop, interoperate with tactical systems
- Many easily repeatable exemplars using Web Services

<http://www.MovesInstitute.org/xmsf>

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## XMSF Partners



- Naval Postgraduate School
  - Dr. Don Brutzman, Curt Blais
- George Mason University (GMU)
  - Dr. J. Mark Pullen
- SAIC Inc.
  - Dr. Katherine Morse
- Old Dominion University (ODU) VMASC
  - Dr. Andreas Tolk








## XMSF Sponsors

- Defense Modeling & Simulation Office (DMSO)
- Navy Modeling & Simulation Management Office (NAVMSMO)
- Defense Threat Reduction Agency (DTRA)
- U.S. Army TRADOC Analysis Center (TRAC) Monterey
- Joint Forces Command (JFCOM) Joint Experimentation Directorate (J9)
- Joint Advanced Distributed Learning (ADL) Co-Laboratory
- USAF Joint Synthetic Battlespace (JSB)
- Chief of Naval Operations (CNO) OPNAV N81 - Assessment



## What is 3D?

- 2\_D works for chart-oriented displays
- 3D gives “fly-thru” freedom of viewpoint
  - View physically based propagation paths
  - View depth separation
  - View bottom, surface interactions
  - View multiple overlapping sensors
- Augment (not replace) existing displays

## What is X3D?

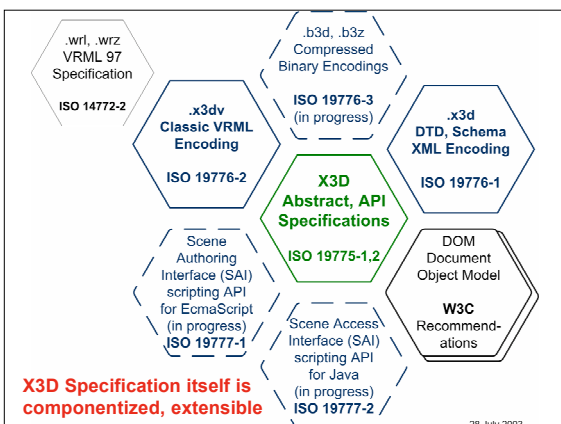
- Extensible 3D (X3D) Graphics
  - Virtual Reality Modeling Language (VRML) updated
  - Third-generation ISO specification
  - Compatible XML .x3d and Classic VRML .wrl encodings
- Deliverables
  - Specification updates, with compatible XML tagset
  - Multiple implementations, including open-source
  - Scene Access Interface (SAI) strongly typed API
  - Conformance suite and examples
  - Authoring capability: X3D-Edit, using XML for XML....

## Further X3D motivations

- Authoring is hard, “Content is King”
  - X3D is not competing with specialty formats, instead provide common interoperability/interchange
  - Strong validation checks eliminate most authoring errors before content escapes
  - Plays well with next-generation Web languages

**“3D hardware problem” is already solved ☺**






## X3D now an ISO international standard

### News Release

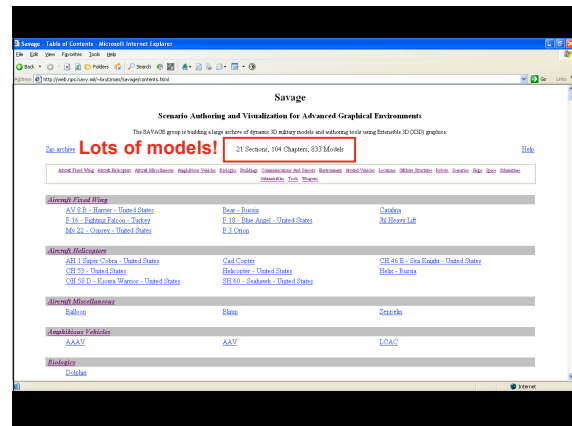
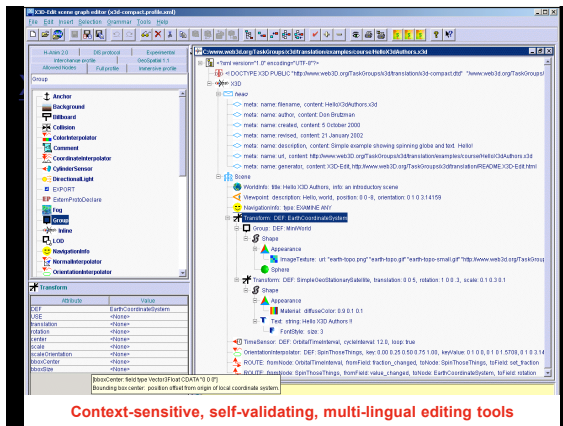
Neil Trevett, President, Web3D Consortium,  
+1 (408) 464 7053, [neil.trevett@3diabs.com](mailto:neil.trevett@3diabs.com)

#### Web3D Consortium Announces X3D Specification Approved as ISO International Standard

Unanimous vote to advance X3D as ISO 19775: X3D evolving to enable and encourage new markets for communicating real-time 3D

August 9, 2004 – SIGGRAPH – Los Angeles - The Web3D Consortium today announced that the X3D® specification has been approved by the International Standards Organization (ISO) as International Standard **ISO/IEC 19775** with formal publication expected in October 2004. Developed and tested within the Web3D working group process, X3D is the Web3D Consortium's foundation technology for enabling real-time 3D communication across networks and between applications and it was unanimously approved by fourteen national committees within ISO. Web3D/ISO specifications for X3D, a royalty-free standard, are available online at [www.web3d.org/x3d/specifications](http://www.web3d.org/x3d/specifications).



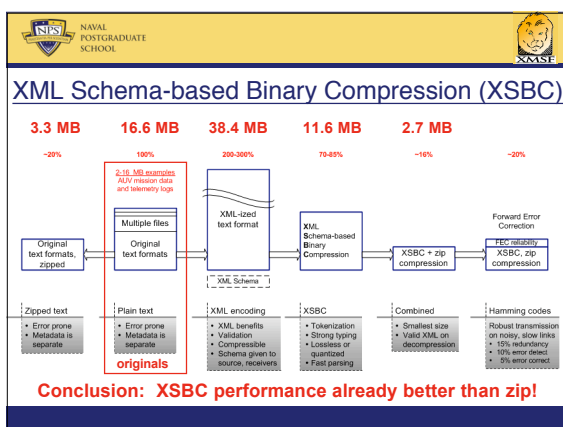


### XML Schema-based Binary Compression (XSBC)

- XML encoding for validation benefits
- XML schema contains adequate information
- Tokenization of elements, attributes
- Strong data typing of value payloads
- Lossless
- More efficient than compressed numeric text
- Faster parsing and run-time performance
- Fix potential showstopper to military XML use

### XSBC Compression of mission scripts

- Compression of mission command file
- XML Schema-based Binary Compression (XSBC)
- Take advantage of XML self-validation capability
- Building composable filters for integrated data support
- Critical capability for military communications links
  - Radio frequency (RF), acoustic



### Forward error correction (FEC)

- Added redundancy allows receiver-side detection & correction of message errors
  - Many military channels are noisy RF links
  - Avoids "retry until you die" on acoustic links
  - Big help on long-latency, low-bandwidth links!
- Hamming FEC is one technique of several
  - Re-exploring Stephen Reimers 1995 thesis "Towards Internet Protocol (IP) over Seawater"



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## W3C and XML Binary Characterization

- World Wide Web Consortium working group
- 2004 charter: establish use cases, properties, metrics for evaluation
- 2005 charter (hopefully): implement and evaluate, create W3C Recommendation
- Big group, active meeting schedule
- Progress and prognosis excellent

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## XML Tactical Chat (XTC)

Use of Jabber protocols

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## XTC reference report

- *XML-based Tactical Chat (XTC): Requirements, Capabilities and Preliminary Progress*, Don Brutzman, Don McGregor, Daniel A. DeVos and Chin Siong Lee with Sandra Amsden, Curtis Blais, Duane Davis, Dimitrios Filiagos and Brian Hittner. Naval Postgraduate School, Monterey California USA, 30 November 2003. 160 pages.
- <http://www.MovesInstitute.org/xmsf/xmsf.html#Reports-XTC>

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## XTC Tactical Chat Must-Have Capabilities

<http://www.jabber.org>

**Faster Response Times**

- Collaboration Support
- Used In OIF and Today
- Net-Centric Warfare
- Single-person or Group Messaging

**Proprietary: Bad!**

- Can't Inspect Binary Messages
- Costly Licenses, Unpredictable Support
- Not Interoperable
- Can't Verify Source Code is Secure
- Not Allowed Across Network Boundaries

**Standards: Good!**

- XML messaging, Web Ready
- Jabber: Free Software, Open Standards
- Can Bridge Multiple Protocols
- Open Source: Inspect, Modify, Improve
- Firewall Friendly, Many Applications

JID: [savage@conference.xchat.MovesInstitute.org](mailto:savage@conference.xchat.MovesInstitute.org) [mailto:xmsf-contact@MovesInstitute.org](mailto:mailto:xmsf-contact@MovesInstitute.org)

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## Jabber: open-standard XML chat

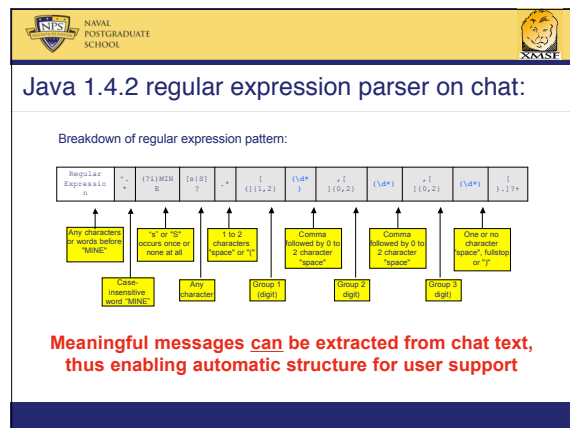
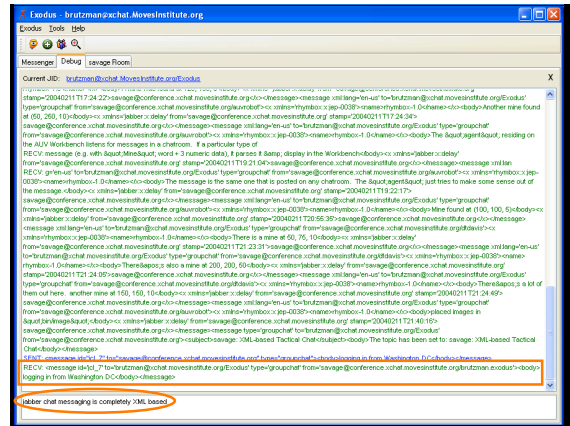
- Extensible Messaging & Presence Protocol (XMPP)
  - RFCs by Internet Engineering Task Force (IETF)
- Active community
  - Many commercial and open implementations
  - Lots of activity developing extensions
  - <http://www.jabber.org>
- Great quick-start for chat technology

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## Military Chat Workshop



- Navy SPAWAR
- San Diego California, dates





- The image is a presentation slide. The top header is yellow and contains the Naval Postgraduate School logo on the left and a cartoon character on the right. The main content area is white and contains the text 'Exemplar work in progress' in blue, underlined, and 'NPS AUV Workbench' in blue. The footer is dark blue and contains the number '48' in white.



## AUV Workbench Project Description



- Open source, Java, XML, X3D graphics
- Mission planning
- Robot mission execution
- Hydrodynamics response
- Sonar modeling
- 3D visualization
- Compressed radio frequency (RF) and acoustic communications




## Robot Mission Planning and 3D Visualization



# Autonomous Underwater Vehicle Workbench



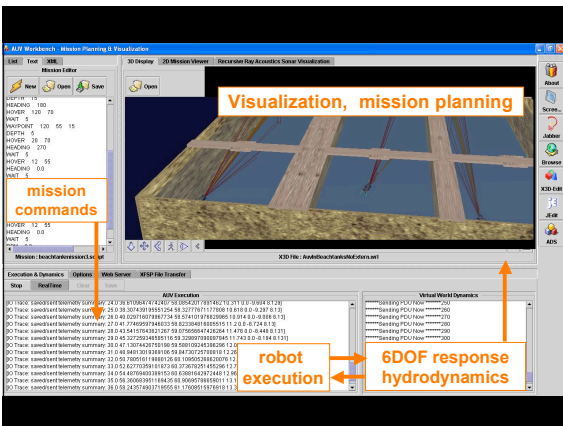



## Our 3 R's: rehearsal, reality, replay

- Same needs and capabilities for each: mission, visualization, data support, etc.
- Refining AUV workbench to support each
  - caveat: ongoing work in progress
- 10 years of effort now coming to fruition
  - integrating great variety of successful work
  - Everything online: source, bugs, email, chat, etc.
- Collaboration is welcome



## Visualization, mission planning



mission commands

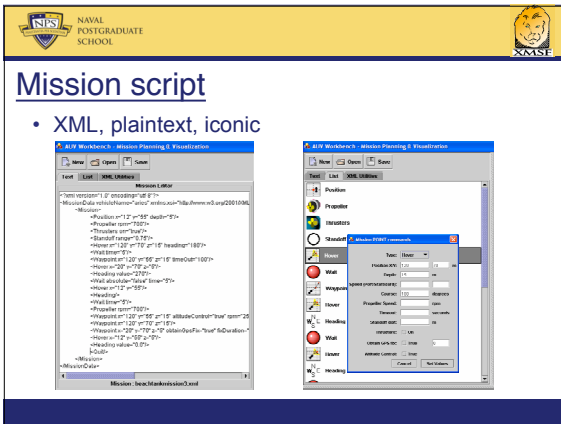
robot execution



6DOF response hydrodynamics

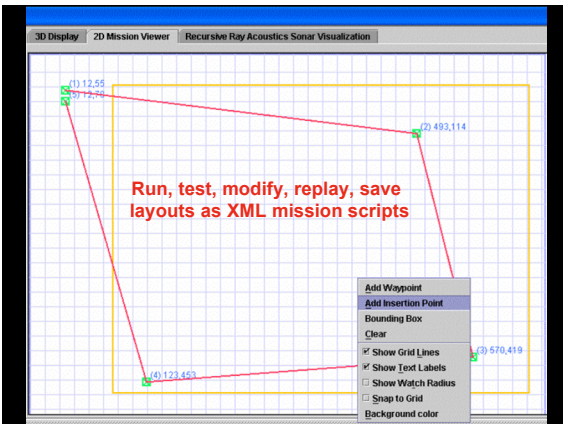
## Mission script

- XML, plaintext, iconic



## Run, test, modify, replay, save layouts as XML mission scripts



Run, test, modify, replay, save layouts as XML mission scripts

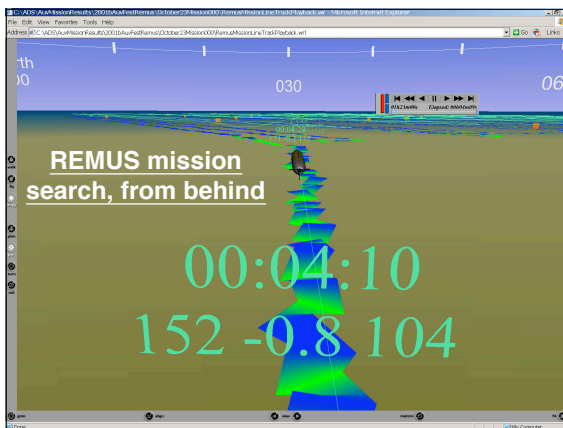
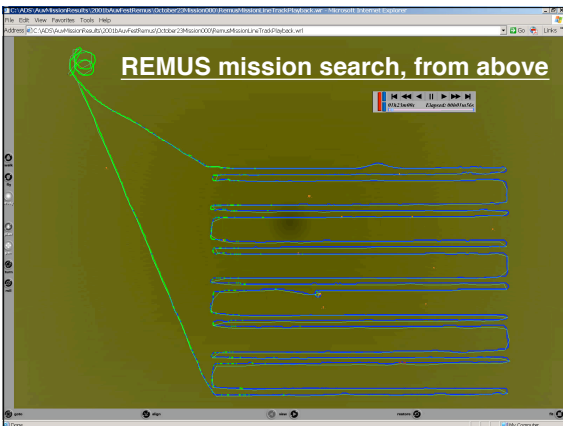


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XMSE

# Physical modeling

- Control algorithms and 6 degree-of-freedom (6DOF) hydrodynamics response
- Sonar propagation, attenuation
- Collision detection
  - Direct vehicle contact and sensor contact
  - Separate use of same X3D graphics models
- Visualization greatly aids understanding
  - provides good “forcing function” for integration



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XMSE

# sonar-vis Project Description

- Visualize multipath 3D sonar propagation
  - Situational awareness, sensitivity analysis
  - Multiple models: path, transmission loss,  $P_D$  ...
  - Operator familiarization, training, experience
- Enhance TDAs for at-sea operators
  - Reachback using Web services messaging, accessing both computational and data assets, locally and from shore-side supercomputers
  - Open source open standards: Java, X3D, XML

# Sonar Visualization

X3D Real-time Analysis with

Recursive Ray Acoustics

LT Scott Rosetti USNR  
xmsef-contact@MovesInstitute.org

# Sonobuoy field visualization

SH-60B Seahawk orbit  
00:07:39, course 315, pitch 0  
location -789 780, altitude 100m

SH-60B Seahawk orbit  
00:03:57, course 135, pitch 16  
location 5772 5228, altitude 191.3m



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## Integrating 2D/3D interfaces with Web Services

Participating in RIMPAC, UD 2004 exercises

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## XML web services for METOC data 1

- Query panel and plotted response

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## XML web services for METOC data 2

- Monitoring initial query/response sequence

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## XML web services for METOC data 3

### Server-side supercomputer response

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## Next steps, lessons learned, conclusions, recommendations



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## Demonstrations at I/ITSEC 2004

- Interservice Industry Training Simulation Education Conference (I/ITSEC)
  - December 6-9, Orlando Florida
- Multiple demonstrations across show floor
  - X3D, XMSF, XSBC, XTC, C2IEDM
  - Multiple government, industry partners
  - multiple domains & locations connected: supercomputer, underwater/airborne robots in Monterey, George Mason University Fairfax VA, NUWC Newport RI, etc.
- <http://www.iitsec.org>



## Lessons learned

- XML, web services are ready for prime time
- Robots are potential "C2IEDM speakers" too
  - Along with people (operators) and C4I systems
- Binary XML compression is essential for military communications links
  - Radio frequency (RF), acoustic, etc.
- It's really all about the XML messaging
  - Not just heavyweight database synchronization
- XML Tactical Chat: shared real-time comms

## Conclusions


- C2IEDM has much promise
  - Even more than shown in current C4I systems
- Rich mix of compatible XML technologies
  - X3D: Extensible 3D graphics
  - XMSF: Web services for modeling & simulation
  - XSBC: Binary compression of XML
- New XML-based capabilities are emerging
- Interoperability on everything

## Recommendations

- Need a document-centric XML version of C2IEDM to support military messaging
  - Is there a review forum or standardization effort?
- XML tactical chat is a new message channel
- Plan for robots as emerging players
- When wrapping and unlocking stovepipes with XML messaging, use C2IEDM
- Build exemplars – walk the walk

**Collaboration and questions welcome**

## Contact

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 Monterey California 93943-5000 USA  
 1.831.656.2149 voice  
 1.831.656.7599 fax







## **Next Generation Distributed Sensor Networks**

**S. S. Iyengar<sup>1</sup>, G. Seetharaman<sup>4</sup>, R. Kannan<sup>1</sup>, A. Durrezi<sup>1</sup>, S. Park<sup>1</sup>, B. Krishnamachari<sup>2</sup>  
R. R. Brooks<sup>3</sup> and J. Morrison<sup>4</sup> 1<sup>st</sup> LT USAF**

<sup>1</sup>Dept of Computer Science, Louisiana State University, Baton Rouge, LA70803-4020

<sup>2</sup>Dept of Computer Science, Univ of Southern California, Los Angeles

<sup>3</sup>Dept of Computer Science, Clemson University, NC

<sup>4</sup>AFIT ENG, Air Force Institute of Technology, WPAFB, OH

### **1. ABSTRACT**

Distributed sensor networks operating through wireless communication offer a powerful means to sense, analyze and respond to dynamic environments spread over vast areas. Latest developments in micro electro mechanical sensors (MEMS) and related devices offer several technical and operational advantages making distributed sensor networks as a viable approach. Robustly packaged, inexpensive, energy aware and tamper proof sensors deployed in massively as an ad-hoc wireless sensor network add a whole new dimension to several high impact applications such as air port surveillance, traffic monitoring, environmental monitoring, surveillance against bio-terrorism, battle field damage assessment etc. In short they permit pervasive, persistent and high endurance monitoring of hostile environments. This paper is an introduction to some of the exciting information processing problems that are being solved to effectively harvest the benefits of current and emerging nano, micro, and macro sensors in distributed sensor networks.

### **2. BACKGROUND**

Nano technology is one of the intensely researched areas at present. A number of nano and micro sensors are being introduced each month ranging from biological sensors to complex RF and optical sensors. The mass volume production and inexpensive fabrication of these sensors make them a viable candidate to propel the art of surveillance and monitoring of wide spread areas. Adding fuel to this idea is long-life batteries, energy aware CMOS circuit designs, and hybrid CMOS-MEMS integration techniques which are at the forefront of technology. An impressive array of packaging techniques exist and new ones are being steadily developed to help deploy these sensors in hostile conditions in large numbers.

Most hostile conditions and events of single occurrence do not permit redeployment or replenishing of the batteries in situ the sensors. Also, it is not possible to pre identify the network topology. It is required to have a systematic way of establishing a network among the sensors after they have been deployed, and gather information robustly in a maximally pervasive, persistent and enduring fashion. Sophisticated information processing tasks must factor this into account.

The September, 1999, edition of Business Week stated that the next generation of distributed sensor networks introduces important new technologies for the 21st century. Likewise, the



February, 2003, edition of MIT's Technology Review identified sensor networks as one of the top ten emerging technologies. The July 2003 issue of the IEEE Proceeding is devoted to micro and nano sensors. The August 2004 issue of IEEE Computer Magazin gives an excellent introduction to the state of the art in wireless sensor networks.

The motivation for sensor systems is the intelligent gathering of sensor data, processing the data, and understanding and controlling the processes inherent to the system. Pervasive micro sensing and actuation has revolutionized the design and management of extremely complex physical systems. The revolutionary shift in paradigm is very similar to the invention of SIMD parallel computers in the late seventies. The focus at that time was: instead of building one very high performance computer, a well conceived network of very simple processors could be built and operated in single instruction multiple data mode to accomplish very high performance computing. The Connection Machine, and MassPar machines built using this approach have demonstrated the merit of this approach. A similar revolution is taking place in surveillance and monitoring techniques based on large network of very simple sensors and extremely simple network topologies.

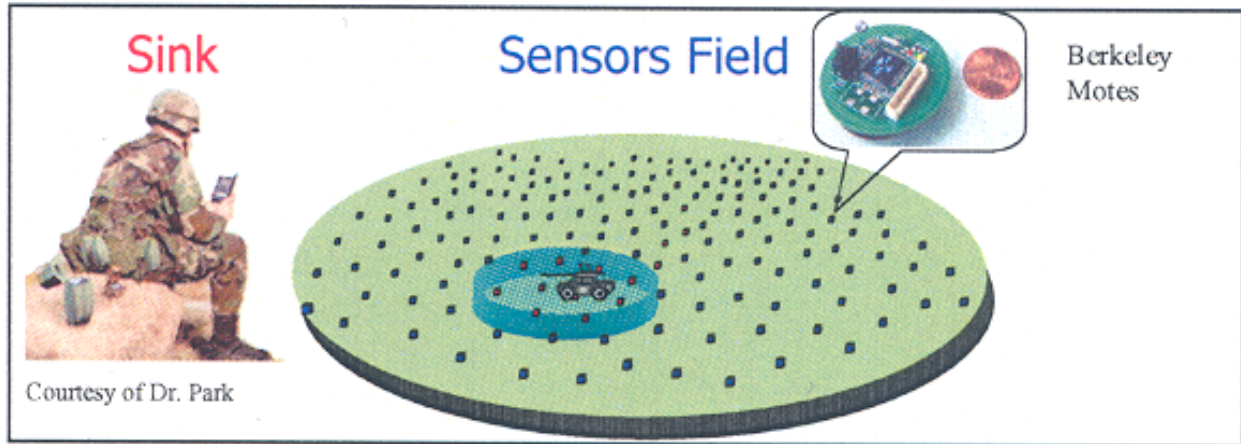
### **3. INTRODUCTION**

Sensor networks can be viewed as a distributed autonomous system for information gathering, performing data-intensive tasks such as environment (habitat) monitoring, seismic monitoring, terrain surveillance, etc. Each node of the network must consist of three components: 1) a variety of sensors to acquire information about the observed space; 2) a wireless communication system to help move the data to end user via the neighbors; 3) a computing / coordinating system to buffer the data, and perform higher level task related to forming and operating within an ad-hoc network. The computing part makes it capable of energy aware, adaptive operation, fault tolerant, and tamper proof.

Elements of a sensor network include the sink which sends queries and collects data from sensors, and the sensor which monitors phenomenon and reports to sink (Figure 1). Typically the outsider (sink) does not communicate invasively to an arbitrary element in the network; his query would be picked up by a nearest node in the boundary, or by one of a few pre-selected subset of nodes. Since communication with a distant sink takes more energy, a typical node should avoid communicating directly to the sink. Thus, there is an asymmetry: the sink can broadcast, but the nodes should not reply directly. There is an implicit tradeoff of involving latency for prudent use of power in favor of endurance.

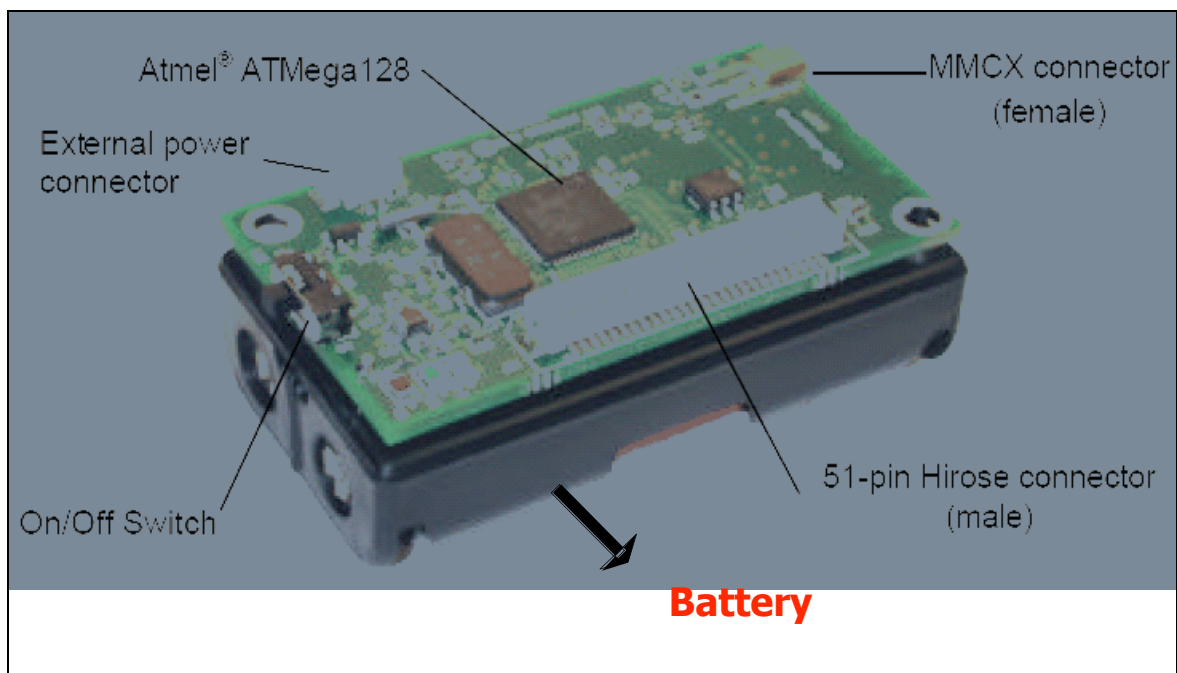
Wireless sensor networks are usually a large number of sensor nodes that can be readily deployed in various types of unstructured environments. They rely on wireless channels for transmitting and receiving data from other nodes. Often, the deployment mechanisms do not permit control over the spatial manifest of the network topology. The sensors-nodes must have native capabilities to detect the nearest neighbors and help to develop an ad-hoc network through a set of well defined protocols.





**Figure 1: Sink and Sensors**

Commercial off the shelf (OTS) components are available to provide the wireless communication aspects of the nodes, allowing the researchers to focus their effort on the sensor design, and analysis of sensed data. Thus, a typical node of a generic sensor network is envisioned as a hybrid structure made of custom designed sensors packaged with OTS (re)motes shown below. A typical sensor mote consists of sensing elements, battery (AA size), processor (less than 20MHz), memory (less than 1MB) and communicating equipment. Figure 2 is an example of a typical sensor node, also widely known as the mote.



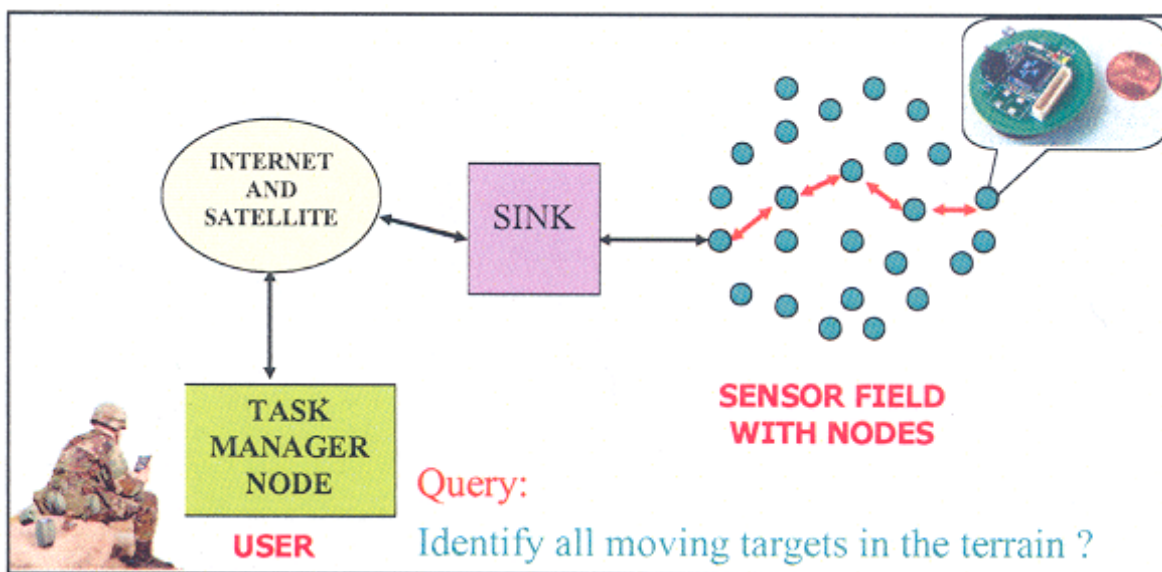
**Figure 2: Typical sensor node. Adapted from Courtesy Crossbow, Inc.**

Sensor network nodes may consist of many different sensor elements. A Sensorcraft [10] is being developed to accommodate a wide range of sensors in a single mobile platform. In this case, it is a small air craft designed carry advanced electromagnetic sensors based on RF-MEMS, FLIR cameras, and CMOS based cameras, an assured data link, onboard GPS and atomic



precision time-reference circuitries. Another article from AFRL Horizons[11] depicts a heterogeneous network envisioned by AFRL with sensors operating in concert. Some nodes of the network remain at fixed positions, whereas other nodes (aircraft) remain in constant motion. Communications travels from aircraft to ground sensors, and vice versa. The network nodes also offer a wide range of sensing and communication capabilities, including distributed ground based sensor networks clustered together to act as a single sensor node. Some configurations will wait to be probed by a flyby sink, while others may risk exposure to report critical events albeit with measured risk.

A challenge in distributed sensor networks is developing an efficient and effective method of extracting data from the network. Figure 3 shows an example of sensor network interaction in which a user submits a query to the network. In this example, the query is submitted to the network through a sink, and is then forwarded to the sensor nodes by local communications links. However, if the same node were to always host sink communications, then, that node will consume battery power faster than other less active nodes. Also, given a limited amount of memory per sensor node, an efficient method of handling communication buffer overflows must also be devised.



**Figure 3:** Network of typical sensor nodes.

A sensor network is an embedded system that should have the following properties:

Self-Configuration - formation of networks without any human intervention

Self-Healing - automatic deletion/addition of nodes without resetting the entire network

Dynamic Routing - adapting routing schemes on the fly based on the network conditions like link quality, hop count, gradient, etc.

Multi-Hop Communication - improving the scalability of the network by sending messages peer-to-peer to a base station.

Three common traffic methods to explore in a sensor network are many-to-one, one-to-many, and local communication. The many-to-one method has the sensor nodes sending data to a base station or aggregation point in the network. For the one-to-many method, a base station or single

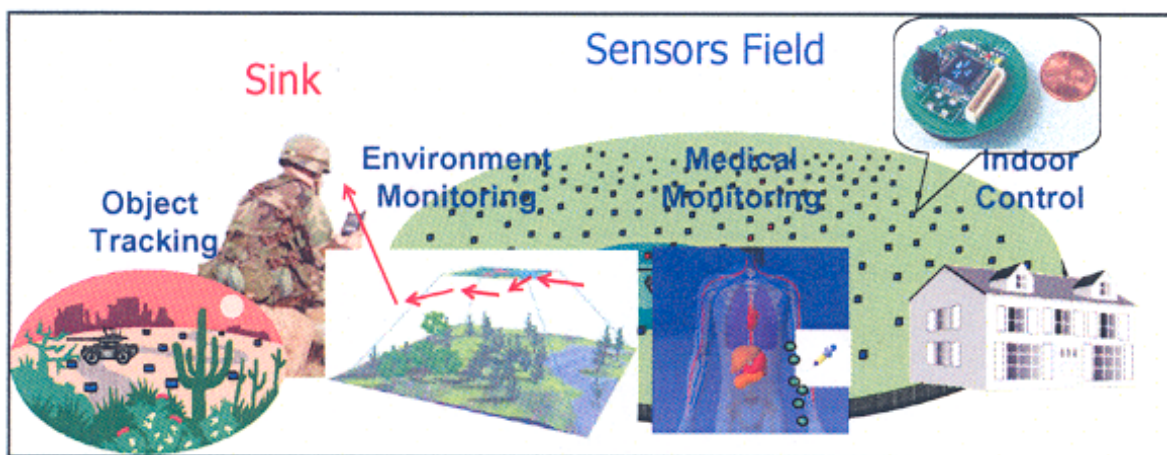


node under a specific condition multicasts or floods a query or control information to several sensor nodes or neighbors. For the local communication method, nodes exchange localized messages to locate and coordinate with each other. The local communication messages may be broadcast or unicast messages [1].

Sensor networks are usually used for either data gathering or an event detection. For data gathering, data should be gathered from the sensor nodes in periodic cycles. A challenge here is to guarantee the system lifetime. For example, communications should occur such that a single node is not burdened with all communications to the sink. For event detection, sensing should occur in real-time. Communication to the base station should be performed only upon the detection of a required event. For both data gathering and event detection networks, measurements from the sensors should be correlated in order to aggregate data. The sensors should also cluster to facilitate aggregation and protocol scalability.

#### 4. HIGH IMPACT APPLICATION OF W-DSNS

Distributed sensor networks can be innovatively applied to a variety of domains (Figure 4). Military applications include surveillance, target tracking, and characteristics measurement of incoming targets.



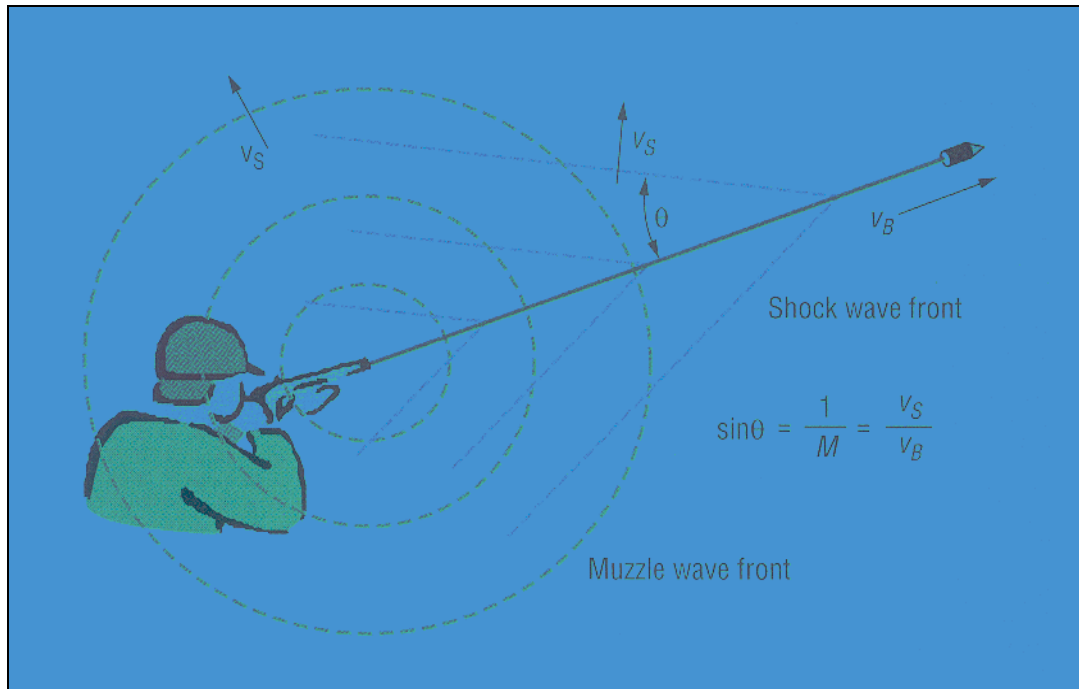
**Figure 4:** Applications domains

The advance of MEMS technology provides new opportunities for distributed sensor networks. MEMS are small, use little power, and are bulk produced. The Jammer Location System (JLOCS) [12] follows a network centered approach to detecting the jamming signals through a widespread set of GPS devices acting as jamming sensors. It is required that we know the self position of the sensors, swiftly determine the direction of arrival (maximum reception) and establish a precise baseline for triangulation. RF MEMS provide ability to generate high radio frequencies in order to super-heterodyne a jammed high frequency signal to much lower frequencies. At lower frequencies, the beat patterns between jammed signals and the jamming signals are efficiently measured and characterized to determine the jammer's location.

Another use of MEMS sensors is measuring sound and pressure activity to determine the location of a seismic or acoustical event. The Sniper Location System (SLOCS) (Figure 5) [13]



uses sensor nodes with numerous MEMS sensors each to measuring its self location, time-of-arrival, and angle of arrival of shock waves. At least two sensors per soldier is essential to measure phase difference and hence angle of arrival. The sniper location and projectile path may be determined from these measurements.



**Figure 5:** Adopted from IEEE Computer Aug 2004.

Interest is also growing in methods of employing stealthy and sacrificial nodes. This challenge addresses the conflicting interest of actively sensing while maintaining stealth (low observability). A sacrificial node may be chosen to emit the energy for active sensing, thus disclosing its location. However, the remaining sensor nodes maintain stealth as they collect the resulting measurements. One or more UAVs act as sacrificial nodes for networks to help acquire data from other stealth aircraft. Atomic precision clock is necessary to coordinate the events. Current state of the art in modeling sensor nodes do not factor in the mobility and exposure (intentional risking of stealth). They do not focus on the time varying spatial configuration of the sensors, which may be manifesting as an elastic mesh, in a collective motion. Inclusion of such factors would be of vital value to problems focused by the micro UAV based SWARM sensing program, and the DARPA MANTIS program.

Another practical example we are studying deals with wide area video surveillance of busy places like airport corridors populated with steadily moving humans. Here the objective is to use inexpensive CMOS digital video cameras, with localized computing, and wireless communication capabilities. The wireless is chiefly needed for inexpensive and rapid deployment purpose only. The networked sensing is necessary to help construct high resolution images, and be able to human gestures. These requirements can not be accomplished by traditional approaches, where only a few cameras are used to image the corridor from a few strategically selected locations. Such systems are inevitably forced use wide angle lenses, and



large depth of field of imaging, resulting in a low pixel count of any observed object. A super resolution imaging would track the subject as he/she moves in the field of view, and inverse compensate the motion, and fuse the video into a high resolution image. In this case, from information theoretic point of view, the motion must be extracted from sources other than video. A large network of extremely simple motion sensor, and/or line of sight optical sensors prove to be effective. Initial results are encouraging [14]. Once again, the choice of implementing this by a wireless sensor network is primarily driven by the economic and logistics constraints rewiring a building to deploy the sensors.

Another exciting application deals with early detection of onset of insidious viruses. The DSN approach to this problem would require a set of geo-sparse internet nodes equipped to communicate amongst themselves through a channel other than the Internet. These nodes form a graph. Each node is able to monitor localized traffic over a periodic interval and compute a local activity vector for each period. All nodes do so in a synchronized fashion. At the end of each period, each nodes communicates with its neighbors its qualitative assessment of the health (activity), and the traffic (port-wise) measure. Then, a discrete relaxation technique would help compute the health of a specific node, based on the perceived health of its neighbors (last frame), and their pair-wise dealings (packet statistics) over the last frame. This method is easy to implement. Analytical tools exist in Computer Vision and Artificial Intelligence to interpret relaxation based results.

For catastrophic events such as chemical or nuclear accidents/attacks, methods to rapidly deploy chemical and radiation sensor networks should also be developed. Sensor networks designed for these events should provide real-time monitoring information for response and rescue missions. Such systems could have been valuable for several incidents:

Dec 3, 1984 - gas leaked from a tank of Methyl Isocyanate in Bhopal, India, leaving 4000 dead and thousands of people permanently disabled.

March 20, 1995 - terrorist released sarin an organophosphate (OP) nerve gas in Tokyo subway system killing 11 and injuring 5500 people.

Feb 6, 2001 - A leak of titanium-tetrachloride at the Tamworth heat treatment factory of Staffordshire, UK, resulted in more than 50 injuries.

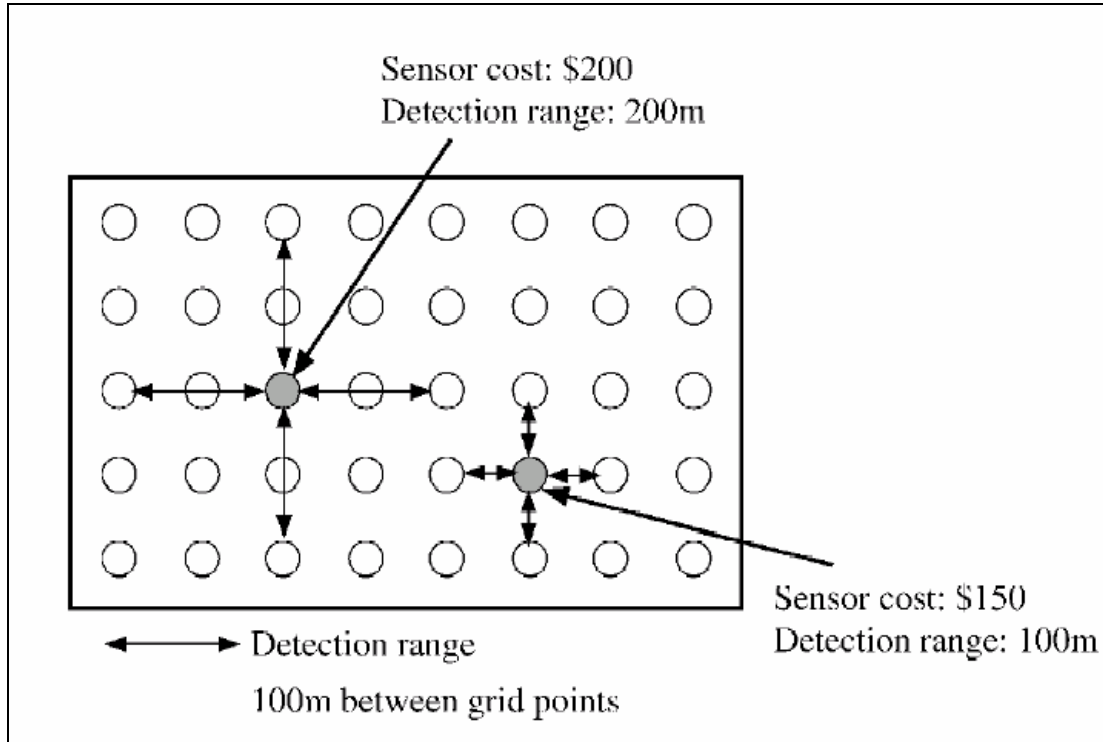
## 5. KEY CHALLENGES: COORDINATED COMMUNICATION ALGORITHMS

There is still a great deal of research and development work to be done in distributed sensor networks. Before resource-constrained sensor networks can be deployed at large scale for long durations in harsh environments, a number of fundamental technical problems need to be solved, such as:

- Self-Configuring Deployment and Coverage
- Efficient Medium Access
- Intelligent Self-Organizing Routing and Querying
- Information Management and Distributed Control
- Fault Tolerance and Robust Operation
- Information Security and Attack-Countermeasures



Addressing these technical problems requires to cutting across all layers, from physical and link to network and application-level. Their solutions require the application of state-of-the-art sophisticated theoretical techniques from many disciplines: coding theory, game theory, distributed control, complexity theory and approximation algorithms, Bayesian inference, network security.



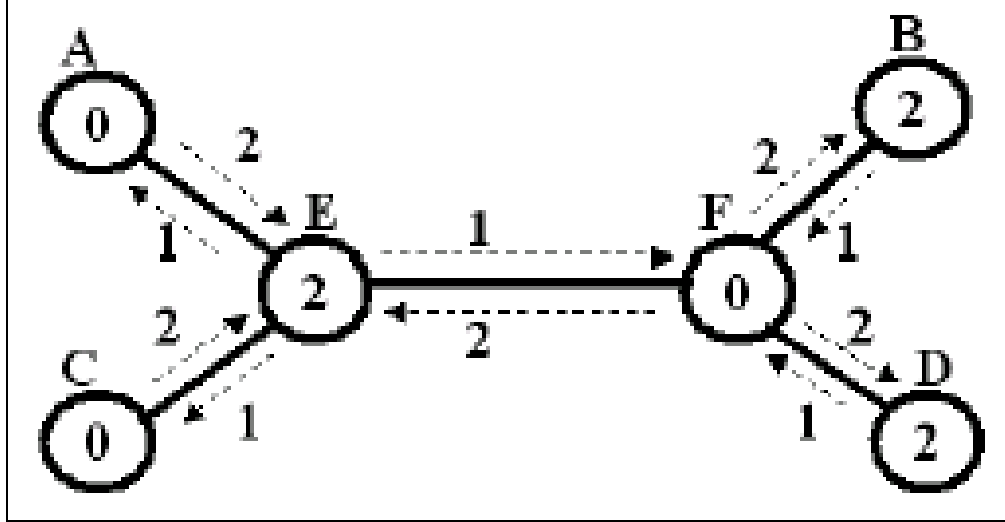
**Figure 6:** An example from of a deployment and coverage problem in a two-dimensional sensor field.

Recently, we have begun forging collaboration between LSU, faculty at Clemson (Brooks), and the University of Southern California (Krishnamachari) to tackle these challenges. At AFIT we are investigating MEMS enabled assured reference devices in JLOCS, SLOCS. Also, early warning virus onset-detectors using collaborative agents across the internet are also being investigated.

Some of our preliminary work is addressing the question of how heterogeneous sensors should be deployed to ensure coverage and connectivity goals are satisfied within cost constraints. Coding Theory techniques such as Identifying Codes are useful for addressing deployment and coverage problems such as is shown in Figure 6 [2].

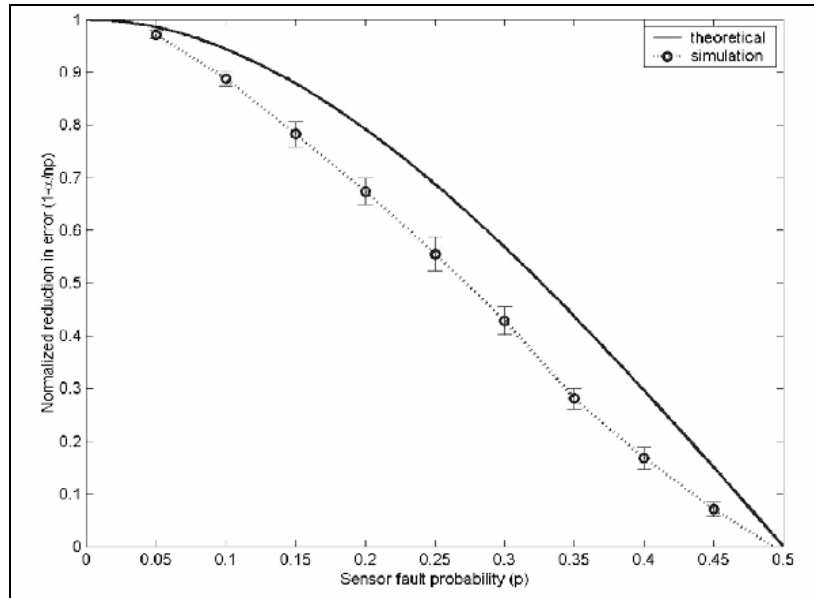
Another area we are studying is the efficient access to the communication medium. To save energy, distributed algorithms (Figure 7) have been developed to coordinate sleep schedules of nodes to conserve energy while keeping communication delay within acceptable levels [3] [4].





**Figure 7:** Sample graph of algorithm to coordinate node communications for efficient medium access.

Also, we have proposed Game Theoretic routing models for reliable path-length and energy-constrained routing with data aggregation [5]. In this model each node (player) will tend to link to the healthiest possible node (the network partition will be delayed). Each node shares the path length cost, with path lengths tending to be as small as possible. Smaller path lengths prevent too many nodes from taking part in a route, reducing overall energy consumption. The Nash Equilibrium of this routing game defines the optimal, Length-Energy-Constraint (LEC) path [5].



**Figure 8:** Normalized reduction in average number of errors for the optimal threshold decision scheme.

Because interoperability between different nodes in a large scale sensor system is inherently difficult, we have developed and evaluated a number of controller design methodologies for hierarchically controlling the behavior of distributed sensor; including Petri Net, finite state



automata (FSA), and vector addition control (VAC) [6]. Also, we have developed a Bayesian interface technique to differentiate between measurement errors and significant environmental anomalies based on localized evidence [7]. This technique can correct more than 90% of errors if the fault rate is less than 10%.

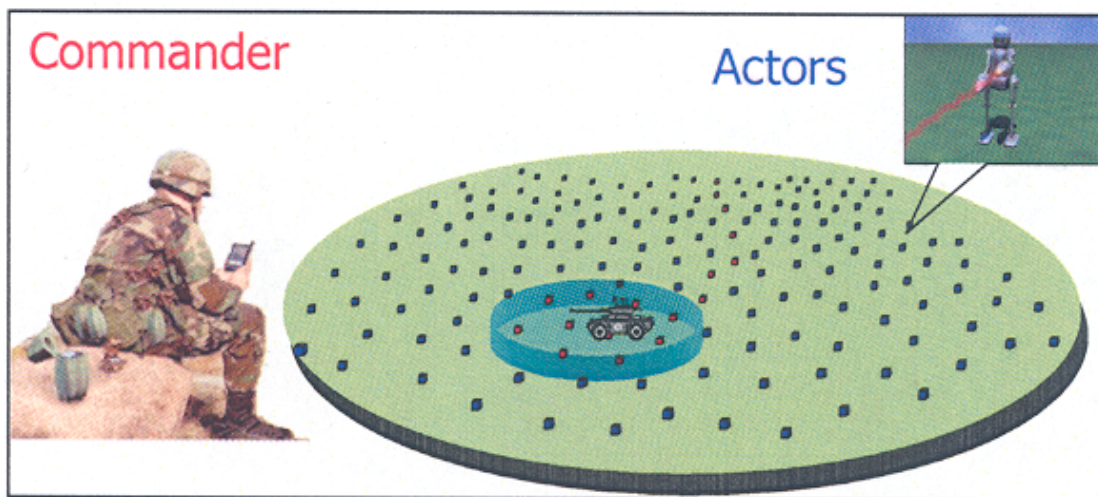
We have also worked on several routing techniques with in-network information fusion in order to aggregating information as much as possible (Figure 9) [8].

Scheme	Bits Used	Savings	Response Quality
No aggregation (NA)	221544	0%	Exact
Header Aggregation (HA)	117544	46.9 %	Exact
HA with Compression (HAC)	100648	54.6 %	Exact
Rectangular Aggregation (RA)	34984	84.2 %	Tight rect. approximation
Circular Aggregation (CA)	34984	84.2%	Tight circ. approximation
Stepwise Rect. Aggregation (SRA)	9240	95.8%	Tight rect. approximation

**Figure 9:** Evaluation of several routing and aggregation schemes.

We are also addressing network security requirements given the severe resource constraints, as traditional cryptographic techniques have unacceptable overhead. One recent development of new distribution protocol providing an efficient tradeoff between security and performance resulted in a 2-phase technique that provable outperforms state-of-the-art randomized techniques at new key [9].

Our next challenge addresses interoperability with Internet and Actor networks. In an Actor Network, an external user, such as a commander, orders actors to perform actions such as changing the environment or attacking targets (Figure 10).



**Figure 10:** Depiction of an interaction between a sensor network and an Actor network.



The issues for interoperability between these networks include development of standard interfaces, authentication and security, and coordination. Due to different protocols at the sensor, actor network, and Internet, it is necessary to provide common and extensible interfaces. Hostile forces make critical the need to provide decentralized authentication methods over Internet or shared wireless media. Furthermore, all autonomous sensor and actor networks should collaborate with each other without human coordination. These are the challenges that the new technology and new ways of thinking have brought in the area of distributed sensor networks.

## **6. CONCLUSION**

Current trends in MEMS and NEMS sensors indicate increased availability of inexpensive and massively deployable sensors to help monitor hostile environments through wireless sensor networks. Steady progress in power aware CMOS circuits, increased access to CMOS-MEMS hybridization, operational advantages of RF-MEMS antennas all make wireless sensor network a common place infrastructure of the near future. Recent research has been focused on both communication and protocols required to operate these sensor networks. We have presented a number of promising applications currently being studied, along with specific communication algorithms developed to perform the power aware routing. Security is an important factor which has not been covered here since it is covered by a number of papers in literature.

## **7. ACKNOWLEDGEMENT**

The authors acknowledge the sources of Figure 2, Crossbow Inc, and that of Figure 5 the IEEE Computer magazine. Also, the research has been supported by various NSF and DARPA grants.

The coauthors' affiliation with The Air Force Institute of Technology does not in anyway imply that the material presented here is the official policy of the United States Air Force. The scientific views stated here are based on the collective scientific conclusions of the authors and not of their employers.

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## **Network Security Issues for the GIG**

**Dr. Scott Hansen**

Northrop Grumman Defense Missile Systems, Reston, VA

This talk addresses some of the Information Assurance (IA)/Security issues that we will be addressing in the Homeland Security and Defense spaces in the near term as we wrestle with the aftermath of the 9/11 incident.

I'm going to talk a little bit about some of the vision in the GIG and the analogous homeland security vision and then talk some about the constraints that are coming down from both sides of the problem space. There are two major IA/Security/Network task forces in our nation underway, looking at the netcentric IA/Security and what are the various issues, these task forces are under the GIG IA SPO at the NSA and the other one is organized under the Markle Foundation. I am sure most everybody in this room knows the NSA and their work. How many people are familiar with the Markle Foundation task force identified by the 9/11 Commission as having a reasonable approach to information sharing that might have prevented the 9/11 incident? Anybody in the room? OK. Maybe I better spend a minute on that Task Force. This was the task force that was stood up to look at the 9/11 terrorist incident and determine what went wrong and what do we as a nation need to do about it to prevent a future occurrence. Not surprisingly they ended up with a network vision that looks an awful lot like the GIG and so I'll talk a little bit about this turn of events and how these are driving the solution set that is evolving in our nation today. Then I'll say a few words about the environments that are going to be different between Homeland Security and Homeland Defense. Both Warfighting and Homeland Security have some unique aspects. I'll also discuss some data origination and relevant time scales that are largely different from the Homeland Security problem, and I'll talk to you about those differences and effects within the decision support environment.

This slide [Slide 2] illustrates the evolutionary transition plan for the GIG. There are three major increments within the GIG vision with deliveries from 2008 - 2016. Increment one, two and three going out a number of years and this is to bring all the networks together and give us that common network backbone in the DoD that was just discussed in this vision.

Interestingly enough going over onto the other side of Homeland Security [Slide 3], in the next slide, and to Mr. Cooper and DHS and you find a very similar set of problems and vision looking for that single converged network backbone migrating from a US Secret backbone which DoD and DHS are starting with to a multi-level secure environment that they have to end with in some future time frame. We talk about complexity in coalition warfare but this HLS/DoD coalition that is you and I, and the cop on the street and your private company that is a much more complex coalition than we are used to dealing with in the DoD arena and will have a very complex rule set. We can easily have people running around with our personal privacy and corporate data that's suddenly part of the terrorism war when we deal with US operations. This personal liberty and private infrastructure aspect that has to be brought into the decision processes makes the problem very different than we have dealt with to date. We have to worry about gatewaying information now and it's not just between the DoD and the Global Information Grid, it goes right on down to the state and local level where the Governor is responsible for the



war against terrorism in his state. Very serious issues of Title 10, Title 32 activity and who controls which data when, how can it be used, what's the governor signing up for, what's the DoD signing up for, what's Homeland Security signing up for are some of the major issues. Make no mistake about this activity as its expected to dynamically collaborative and it will be very temporally dynamic as the situation presents itself that was only vaguely defined before.

DEFINING THE FUTURE NORTHROP GRUMMAN

### Outline

- GIG and HSDN+ Visions and Directions
- GIG IA SPO requirements and Markle Foundation Reports
- Implications for Decision Support Systems

12/13/04 09:58 ONR Decision Support Workshop 2004

Slide 2

DEFINING THE FUTURE NORTHROP GRUMMAN

### GIG 2020 Vision

- Transformational change in the way DOD/IC communicates
  - No more stovepipes

12/13/04 09:58 ONR Decision Support Workshop 2004

Slide 3

This is the first Increment of the GIG illustrated on this slide [Slide 4] that is expected to be completed by 2008, I don't know how many dates I really trust in any of this, but essentially what happens the way we are set up today we've got a top secret network up at the top with all the various security caveats riding it, SIPRNET with all the US Secret and collateral information and then finally the Sensitive But Unclassified (SBU) net down at the bottom are illustrated on this slide. And the first step is to put a black core in place so there will be a common "black core" transport by 2008. So all data will be encrypted and flowing through this black core and come out of the black domain through various gateways, you'll see these are across the main systems that are doing that filtering, and DISA might be a good place to build those, but there will be a lot of activity in those cross domain solutions of being able to move data in some automated way between domains to other agencies and communities of interest.

DEFINING THE FUTURE NORTHROP GRUMMAN

### HSDN Vision (Composite from Multiple Sources)

- Single converged backbone for the HLS Federal Communities
- Migrate from US SECRET to MLS
  - MLS Driven by IC, Federal, State, Local and Private
  - DoD U to SCI (caveat 1-n)
  - DOE Q and L
  - Local/State/Federal LES (1-n)
  - Private Industry Proprietary (1-n)
- Gateways Between SIPRNET/GIG/HSDN+ POPs
- Gateways to State POPs
  - Governor/CISO policy control
- Title 32, 10 and 50 issues
- Collaborative Enterprise Services
  - HLS/DHS/HLA Decision Support
- Dynamic Policy Management

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Slide 4

DEFINING THE FUTURE NORTHROP GRUMMAN

### Increment 1 - 2008

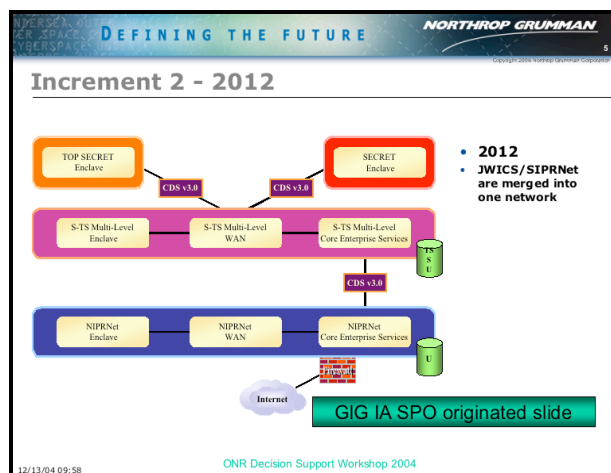
- 2008
  - Current classified networks running over black core

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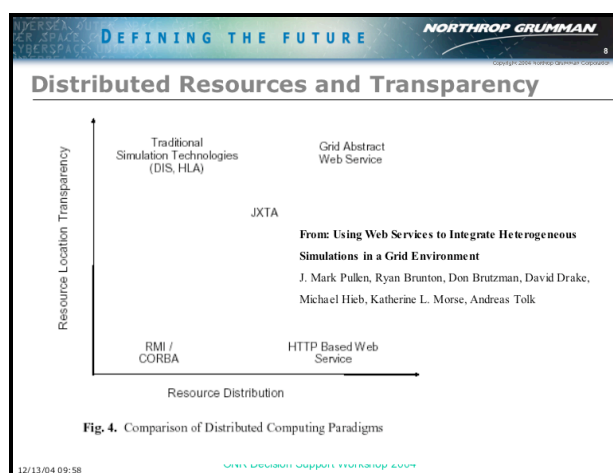
Slide 5



In 2012, the first major collapse in the GIG [Slide 5] is planned of bringing together the top secret and secret network into one major backbone and I have left the black core as well up there that will still be there at that time and there will be ever more increasing complexity in the cross domain solutions of what can move across domains, with when and how, controlled through policy and gateway design/implementations.



Slide 6



Slide 9

I won't spend long on this but the point but service oriented architectures [Slide 6] are a crucial component of being able to have the dynamics needed to address these information sharing situations and to get the services across to users that need the information. And you see this move everywhere in the DoD, DHS and HLS communities. You also see these types of services migrating into cars, you see it in the public safety automation and see the commercial approach migrating capabilities into the DoD through the GIG. Meanwhile this movement is going on in both the simulation community that was talked about yesterday by Andrew and in the C3 space that is the broader subject of this conference. We are going too more transparency in the future about where resources are coming from and how they are distributed. And we will end up eventually with abstract web services for efficient execution of tasks and we will not need to know where the resources come from, the system itself will go find these for you.

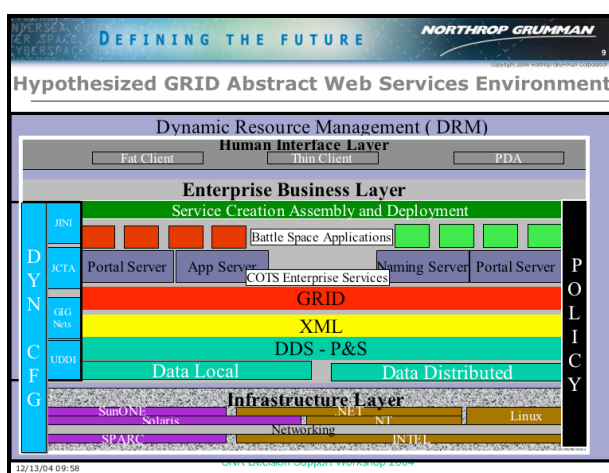
And this vision from the GIG and DHS are starting down that path of what are these services, how will we bring together these dynamic configurations and dynamic resources all driven by the policies that we make [Slide 9]. The art of this new effort is going to be in those policies. And, going back to many things that Dr. Pohl talked about, if we don't have intelligent software, this approach is not going to work. It has got to be there, and it has to be very smart about how we obtain resources, how we combine them, how we put together our configurations and our policies underneath those dynamic resource constraints that we will always have.

This is if it's appropriate down for information access. For example for the first time we are going to be in a situation where the person with the computer with the data with the radio on a classified network is going to be captured and that person will more than likely be cooperative on that network, so how do we balance those problems of access and security. So what we're looking at here is security risk measurement, what is the risk of mission accomplishment against network/information risk. Is the person in a place he can be captured, is he in any place where

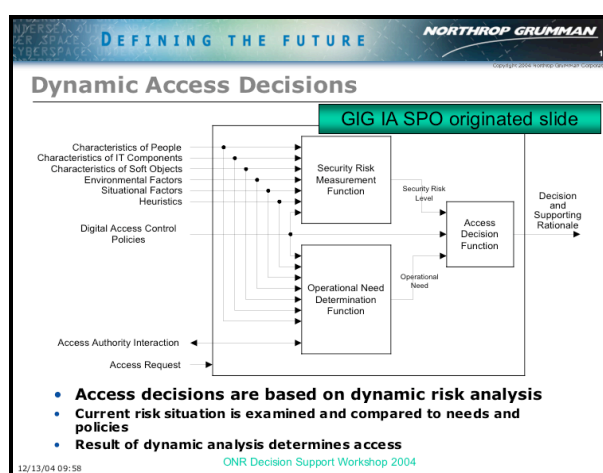


anybody can see his screen with classified information, is he is a place where he is safe, and it is a secure bunker. All those things go into the risk equation, the question is what is the operational need, how much data do you need to do your job.

An interesting example is Blueforce tracking, if the one guy that got captured has access to BFT, you probably don't want to transmit to far where all your friends are around you. So those are the realities we are going to be facing and the NSA task force is addressing this directly and is addressing that how are we going to do this and how is it going to be implemented in the network and across the network boundaries. It goes down to where is data that going to be stored, how much of it, what's its lifespan at that location how is it encrypted [Slide 9]. All of those kinds of things are addressed in what is known as Risk Assessment Demand Access Control (RADAC) illustrated on this slide [Slide 10]. Lots of information is expected to be available to weigh risks to information exposure.



Slide10

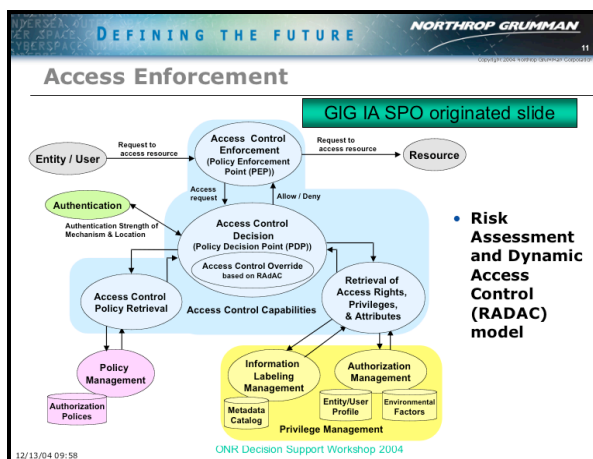


Slide 11

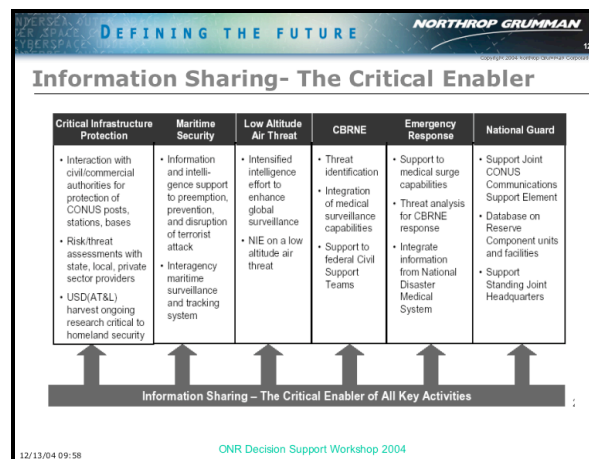
And it is a very complex model of how you decide if you can release it or not to a requesting user [Slide 11]. At least one of the first calculations that was done is to make a transaction in the GIG, that is one IER transaction, there will be 100 other transactions, checking security, finding the resources, doing compiles etc... So there is a lot of work going on, particularly in the task force, trying to pin down how big a problem we are looking at but this definitely goes into the category of hard problems to be worked.

But what is true across all communities, if we don't find a way to effectively share information [Slide 12] in the right time we are out of luck, and this is just the ones out of a defense science force study showing that across the spectrum of the task and the organizations we have that will need to solve the problem. We have to solve it on our warfare and we have to solve it on the homeland security side and we have to go all the way across a very strange coalition to make it a reality in the counter terrorism war.





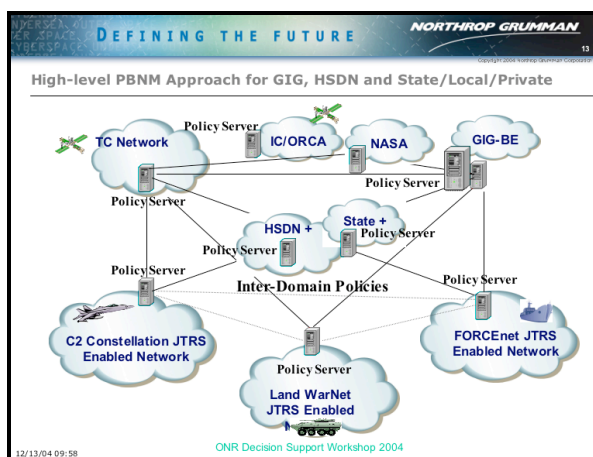
Slide12



Slide 13

This slide [Slide 13] illustrates a joint networking approach with a few other services available to the aggregated system. The concept is that there is going to be one big policy driven system with lots of spheres of influence. All these policies are going to be made, their presence in networks from TC, the air, homeland secure data net, all the way down to the state levels and intelligence community with everybody guarding their data and access to their data controlled through policy driven systems

I am going to go through these Markle Foundation slides quickly, you can read them in the proceedings, or if you want to go up to [www.markle.org](http://www.markle.org) [Slides 14-19]. Once again a very interesting task force sitting down to decide what are the information sharing requirements and what are the security and privacy concerns that we need to look at from a Homeland Security viewpoint of the situation. This viewpoint is from a mixture of technologists and government, and all the way down to the governors who are the people really responsible for our safety in this counter terrorism war within our 50 states.



Slide14



Slide 15



DEFINING THE FUTURE NORTHROP GRUMMAN

Illustration No. 1: Some Characteristics of a Next-Generation Homeland Security Information Network\*

15

- 1. Empower Local Participants
  - Local participants must be empowered to contribute, access, use, and analyze data. At the same time they must be allowed to identify, access, communicate with, and assemble other participants in both the public and private sectors.
  - Expert groups must be allowed to form at the edge of the network. Data should be maintained and rule sets should be developed and implemented by and among local participants. Each should be allowed to undertake as much work as they are capable of doing.
  - Push computing requirements away from the center to utilize excess capabilities at the "edge" of a network, allowing mini-centers to develop around local expertise, which can then be accessible to other network participants.

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Slide16

DEFINING THE FUTURE NORTHROP GRUMMAN

Illustration No. 1: Some Characteristics of a Next-Generation Homeland Security Information Network (Continued)

16

- 3. Create Safeguards and Guidelines to Protect Civil Liberties
  - National security systems should raise concerns about privacy, civil liberties, and due process. To protect against abuse in how information can be used, accessed, or shared, participants need clear guidelines based on our laws and social values.
  - The DHS should take the lead in creating robust permissioning structures and audit trails that will help enforce appropriate guidelines. These critical elements could employ a wide variety of authentication, certification, verification, and encryption technologies. Role-based permissions can be implemented and verified through the use of certificates, for example, while encryption can be used to protect communications and data transfers. A robust Public Key Infrastructure (PKI) or other authentication system within the network, driven by DHS at the core, may turn out to be crucial. Auditing tools that track how, when, and by whom information is accessed or used ensure accountability for network users. These two safeguards—permissioning and auditing—will free participants to take initiatives within the parameters of our country's legal, cultural, and societal norms.

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Slide 17

DEFINING THE FUTURE NORTHROP GRUMMAN

Illustration No. 1: Some Characteristics of a Next-Generation Homeland Security Information Network (Continued)

17

- 5. Design a Robust System
  - The network must be designed and deployed to withstand extreme stress or crisis. Points of failure must be identified and minimized, just as points of access must be maximized to encourage widespread usage among qualified participants. Systems must be designed from the "bottom-up," in order to facilitate dynamic and rapid evolution in response to changing needs. Redundancy, interoperability, and open standards are all elements that constitute robust networks. Ensuring that the network can continue to operate in the event of the loss of a portion of the network is crucial—a so-called "graceful collapse" will prevent catastrophic failures. The ability to find, access, and use data demands common or interoperable data structures and schemas; the industry standard, XML, is an obvious option that can facilitate access to legacy data as well as provide utilitarian structures for to-be-collected data. Meta-data, watermarking, and indexing tools can facilitate data interoperability, storage, and retrieval. Communications standards—TCP/IP, HTTP, and other common Internet technologies—can help simplify and ensure that connectedness is maintained throughout the network. Keeping computation and storage at the edge of the network also allows for redundancy and capacity building.

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Slide18

DEFINING THE FUTURE NORTHROP GRUMMAN

Illustration No. 1: Some Characteristics of a Next-Generation Homeland Security Information Network (Continued)

18

- 10. Create a Connected Culture
  - A cooperative, collaborative culture is required for the success of dynamic connectedness. Just as individuals are empowered through next-generation network designs, participants must also support the successful exploitation of these technologies through positive reinforcement, peer pressure, and accountability as well as repudiation of users who abuse the system. Feedback systems that reward valuable contributors will help establish credibility both for individual participants and the network as a whole. Reliable, robust, and secure communications will encourage interactivity. Appropriate and verifiable permissioning systems will support the development of trustworthy relationships. Networks that drive both electronic and traditional collaboration can create a mutually reinforcing environment for all involved.

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Slide 19

I am going to go through these slides quickly but you will see things very similar things to the GIG in this slide set, this is the concept of power to the edge, of course they have likely never heard of that term on the homeland security side of the discussion but it is essentially what they are saying here.

A little bit different take on this, this network is going to have our private data in it so how is it going to be protected, how are we going to put permissioning structures in place to guarantee that our privacy will be enabled and protected and similar role base permissions for getting to that data so you see very similar things to what we see in the GIG for enabling technologies.

And essentially this is what they are looking for GIG and HLS sides of the problem. We are both looking for a dynamic and connective set of technologies that allow all the people that need to solve a particular problem set onto a "network" at the right time, but at the same time ensuring that the network is secure and the authorized policy permissions are actually enforced.

One can ask what is the scale and the time of all of this technology implementation and that is still to be determined, but you do see people moving out the everywhere and this may actually



accelerate some of the things we are talking about here. There are a lot of people on the many sides pushing pretty hard to get these information sharing technologies in place.

This is the simple picture [Slide 20] of a future information sharing environment and how it might come about. I think I put the GIG AI requirements in context and then I compared it to HSDN you have a vision of this give and take on both sides and I should say the homeland security data that I am talking about here is very large compared to typical DoD warfighting data sets as it is everything that comes out of DHS/HLS lumped into one set of data at this point.

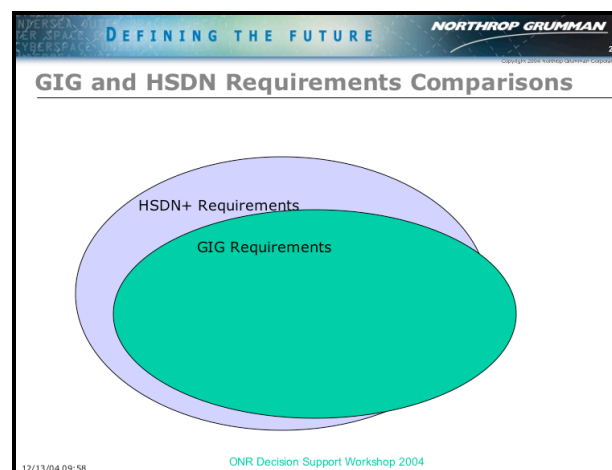
DEFINING THE FUTURE NORTHROP GRUMMAN 19

### The call to action

"This is government acting in new ways, to face new threats," the most recent Markle report explains. "And while such change is necessary, it must be accomplished while engendering the people's trust that privacy and other civil liberties are being protected, that businesses are not being unduly burdened with requests for extraneous or useless information, that taxpayer money is being well spent, and that, ultimately, the network will be effective in protecting our security." The authors add: "Leadership is emerging from all levels of government and from many places in the private sector. What is needed now is a plan to accelerate these efforts, and public debate and consensus on the goals." 911 Commission

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Slide 20



Slide 21

It is actually more complicated than that as this slide [Slide 21] illustrates. This is from the DSB Homeland Security Report again, looking at bringing together homeland defense its power projection, the homeland security piece, looking at DoD's dependent on the infrastructure which they live within, 75% of all the enabling capability for our bases here in the US are actually in the private sector, so that's the best that's generally the weakest link if you want to go after DoD warfighting capabilities. But this system we are discussing it what brings them all together. These are a lot of different communities of interest and sorting all this policy and technology out is going to take some time but it will happen if we are to increase our collective security.

What this comes down to is that we are looking at right now is migrating from an enclave security model down to where information has to be encrypted on your device to maintain end-to-end security. If that device is actually going to be captured you really don't want someone running around with all the everyone else's and your data on it. And then other issues such as how do you protect the jeopardized personnel, the information, continue your mission and protect the network. How do the network security folks realize when capture and/or potential capture events take place in this mobile networks of networks? The larger problem in mobile world now is how do we get identity, authorizations, behavior and keying material for all that data/information to the right place at the right time. Some of this is started already if you look at your credit cards and you go around different places they now have the behavior models up and running. For example we the credit card authorization system realizes that you weren't there (typically overseas) last week and why are you buying it there now, so we'll hold your card authorization for you until you call us and tell us you're the right person. So this is a beginning of the operational behavior modeling for the service access. And there is lots of work going on



But I will walk you through the MDA example here very quickly. There are some definite bottom line changes in the way security is done and the way networks will be architected in the future, how the data will be protected, how you get to that data, how you authenticate yourself, all of those kinds of things are going to be fundamentally changed from what you know today to meet this kind of mission. In this culture this is expected to be a broad movement over a considerable time frame. You've got the "coalition" illustrated here on the DoD side and then the Homeland Security "coalition" illustrated there over on the other side extending all the way from the president right on down to the local citizen response team working homeland security activities. A lot of very different data and networks will have to come together to optimally address this type of homeland security and homeland defense issue in some optimal way. [Slide 22]



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# Generative Lexicons for Extracting Concepts from Text Documents

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## Abstract

A key goal of information-centric software is to achieve interoperability among decision-support systems. Architectures for supporting this vision typically involve a set of collaborating agents along with a common ontology for sharing information. This will require integrating legacy data-centric systems that provide access to relevant data sources. We address the problem of integrating such systems when these sources are in text format. Thus, our challenge is to identify the conceptual content of text sources to facilitate its sharing and integration. Natural language processing (NLP) technologies are the primary means for identifying and extracting concepts from text. However, existing NLP techniques that use traditional sense enumerative linguistic ontologies are severely limited for supporting this task, and suggest that a form of generative linguistic ontologies be used instead. We describe FACIT, our knowledge extraction framework, and highlight its use of generative sublanguage ontologies, an extension of generative lexicons, to support knowledge extraction. We also summarize our work to date on this framework and describe future work needs and interests.

**Keywords:** Knowledge extraction, text documents, generative linguistic ontologies

## 1. Introduction

The US armed services are developing net-centric warfare (NCW) concepts and systems for achieving their information superiority goals (Alberts et al. 1999). These goals include the ability to collect, process, and share information while preventing adversaries from doing likewise. The potential impacts on warfare concepts and mission execution are enormous, and will significantly change the way warfighters operate.

Decision support systems play a pivotal role in the design and implementation of NCW goals. In particular, systems that implement teams of software agents are expected to increasingly support decision makers with the ability to quickly process and fuse sensor information, construct common operational pictures for situation assessment, provide an overview of the decision space, and convey an understanding of the ramifications of making these decisions.

These goals require that agents be interoperable and, in particular, be able to access and share information towards achieving their respective decision aiding tasks. However, achieving interoperability is difficult, and its lack thereof is a primary information systems problem (Pohl 2001). Pohl explains that obstacles to interoperability can be overcome by embedding the integrated system in software that has some understanding of the data being processed, and this requires addressing issues concerning its representation.



We address a subset of the interoperability challenge that focuses on sharing text documents. We describe a technique for representing term meanings (*generative sublanguage ontologies*) for identifying and extracting concepts from text documents, a framework that uses it for document interpretation, and our partial implementation of this framework. We exemplify our approach and discuss related and future work.

## **2.1. Knowledge Extraction for Decision Support**

Decision support systems are designed to assist their users with situation assessment and perform decision analysis. These systems are typically interactive and allow the user to control their decision-making. A primary characteristic of decision support systems is that they must be provided with a domain description in which decisions are made and the access to pertinent heterogeneous data sources. Information from these sources must be extracted and integrated to assist with situation assessment and decision analysis. Data can be in many modalities (e.g., speech, imagery, video, text).

We focus on issues pertaining to extracting information from text sources that are semi-structured. Examples of such sources in NCW include OPORDS (operations orders), doctrine, TTPs (Tactics, Techniques, and Procedures), AARs (After Action Reports) from previous missions and exercises, and lessons learned. Our motivating task concerns the sharing and integrating of lessons learned documents in decision support systems. We describe this task in Section 2.1 and present our approach to solve this problem in Section 2.2.

### **2.1.1 Motivating task**

HICAP is a mixed-initiative plan authoring tool suite that speeds up the process of deliberatively planning a course of action (Muñoz-Avila et al. 1999). HICAP supports its users with their planning decisions. In particular, using a hierarchical planning representation, it helps the users decide how to decompose a given task via a mixed-initiative situation elicitation module that provides access to previous <situation, decision> experiences. It also contains an automated plan decomposition module that can accelerate plan authoring at nodes where the subtasks can be automatically selected.

We also integrated HICAP with ALDS, a case retrieval tool that proactively identifies relevant Navy Lessons Learned (NLLS 2004) and brings them to a user's attention when they apply to the current planning situation (Aha et al. 2001; Weber and Aha 2002a). While HICAP operates, ALDS silently monitors the situation being described by the user and compares it with the stored lessons, which are represented as <task, situation, decision> cases. Those lessons whose task and situation sufficiently match the current planning task and its situations are brought to the user's attention. Next, the user can decide whether to automatically apply a suitable adaptation of the retrieved lesson's decision (e.g., a plan decomposition, a resource substitution) in the current planning context.

Creating a case library for ALDS requires a significant knowledge engineering effort. In particular, this requires a domain expert to identify a lesson's task, specify the situations that must be met for the lesson to apply, and provide the lesson's recommendation framed as a planning decision. Manually creating such lessons is a tedious and potentially error prone process. Two approaches could be used for lesson acquisition. First, a lesson elicitation tool could be developed that guides users through the process of collecting lesson content in the



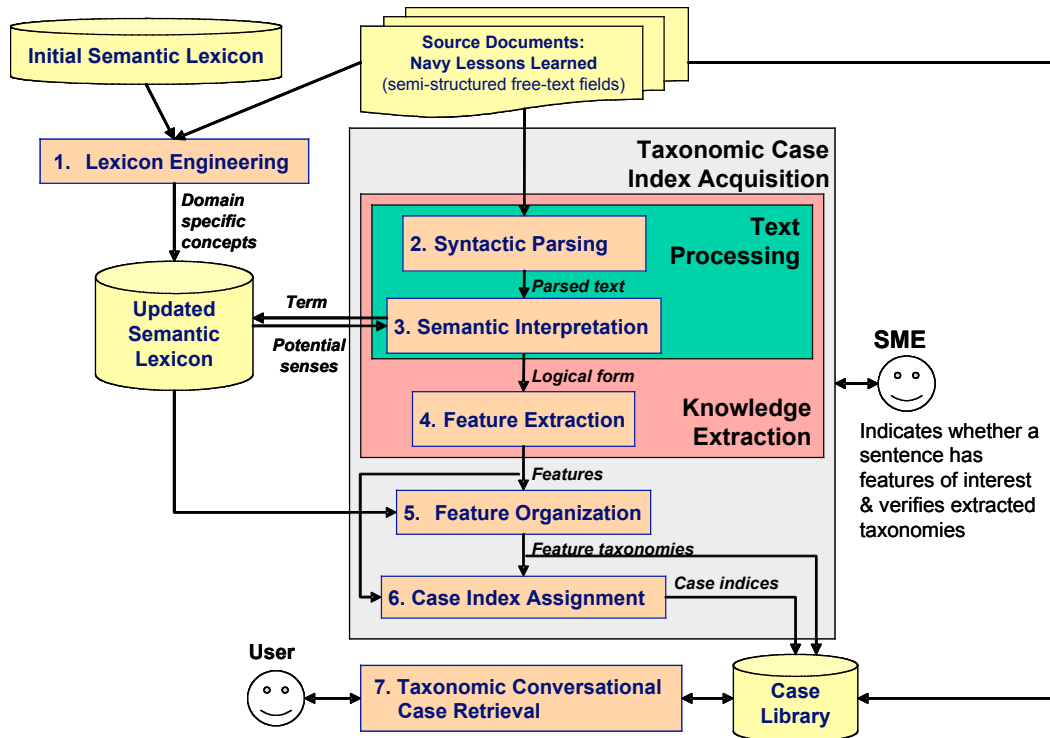


Figure 1: The FACIT knowledge extraction framework.

computable representation used by ALDS. We developed the Lesson Elicitation Tool (LET) to meet this need (Weber and Aha 2002b). However, this approach ignores the huge body of existing lessons learned. The computable representation for existing/archived lessons must be derived using a knowledge extraction process. We describe this second approach in Section 2.2.

### 2.2.1.1 The FACIT knowledge extraction framework

We created a framework for extracting case indices from archived lessons. Our framework, named *FACIT* (Feature Acquisition and Case Indexing from Text), is displayed in Figure 1. *FACIT* updates the semantic lexicon and uses it for syntactic and semantic interpretation to create a logical form, which is a set of sentences represented in a predicate argument structure. It then extracts features from this logical form to index cases. This process involves the seven steps shown in the Figure 1.

*FACIT* has several novel characteristics. First, it operates on semi-structured text documents, which distinguishes it from other frameworks that instead perform concept extraction under strong assumptions on text structure and content. Second, it uses a semantic lexicon inspired by a generative approach (Pustejovsky 1995), which permits it to robustly identify concepts. Third, it implements a *knowledge extraction* process (Cowie and Lehnert 1996); it is not told a priori which features should be used as case indices; instead it must depend on a subject matter expert to interactively identify useful features in a few sample sentences. Fourth, it represents case indices in a set of feature subsumption taxonomies (Gupta 2001).

We describe *FACIT*'s steps in the rest of this section. We then summarize *FACIT*'s implementation status in Section 3, and describe related and future work in Sections 4 and 5, respectively.



### Step 1: Lexicon engineering (with generative sublanguage ontologies)

As shown in Figure 1, semantic interpretation and feature organization depend on the availability of a semantic lexicon, also known as a *linguistic ontology*. These ontologies encode a domain's terms and their corresponding conceptual representations. This permits linguistic ontologies to look up a given term's potential senses (*concepts*) and use a disambiguation technique to select the most applicable sense among them. However, domain-independent linguistic ontologies (e.g., WordNet (Felbaum 1998); SENSUS (Knight and Luk 1994)) have poor coverage for domain-specific text applications. For example, WordNet covers only 25.6% of the terms in the naval training exercises domain that we extracted from a subset of Navy Lessons Learned (Gupta et al. 2002). WordNet's coverage of senses is likely to be even lower because it lacks domain specific senses for known terms. Consequently, lexical resources must be updated to include domain specific terms and their senses. Thus, issues of concern include the choice of lexical representation and the effort required to update it.

Linguistic ontologies can be categorized as either *sense enumerative* (e.g., WordNet, SENSUS) or *generative* (Pustejovsky 1995). Table 1 compares these two types of ontologies. Sense enumerative variants, which require listing every sense of a term or phrase in the lexicon, have weak lexical semantics (i.e., they incorporate only a few impoverished relation types between concepts), weak compositionality (i.e., they cannot derive unlisted meanings of a term), and large sense ambiguities. Thus, the effort to update them increases linearly with the number of unknown senses and terms. In contrast, generative linguistic ontologies include rich, well-principled semantics and do not require explicitly listing all potential senses of a term. Instead, a small set of powerful operators generates them on demand based on their context of use, substantially reducing the sense disambiguation effort as a consequence. Generative linguistic ontologies support strong compositionality and can derive senses of previously unseen combination of terms. Finally, the effort required to update generative linguistic ontologies is sub-linear and comparatively marginal.

A *Generative Lexicon* (GL) (Pustejovsky 1995) is a type of generative linguistic ontology that was developed by computational linguists to address some of the problems inherent with sense

**Table 1:** Distinguishing sense enumerative from generative linguistic ontologies.

Characteristics	Sense Enumerative	Generative
Number of entries (size)	Large: one concept per sense of a term	Compact: One concept per set of related meanings of a term
Interpretation robustness	Brittle; fails if required sends is not lexicalized	Robust; generates unanticipated senses, and degrades gracefully
Compositionality	Low	High
Disambiguation support	Low	High; part of sense selection and generation
Maintenance	High	Low
Available implementations	Many	None?

enumerative linguistic ontologies. Briefly, a GL attempts to represent multiple related meanings



of a term (i.e., *systematic polysemy*) using a well principled conceptual structure. This conceptual structure has four primary components:

1. *Arguments*: These are a concept's logical arguments.
- 2.1. *Qualia*: These represent a concept's defining attributes (e.g., constituent parts, purpose).
- 3.1. *Events*: These define a concept's event structure.
- 4.1. *Inheritance*: These permit a concept to inherit the first three elements from its parent.

In addition, GLs generate and select the meaning of a term in its context (i.e., other terms related to a term by syntactic structure), when syntactic and semantic constraints fail, by using generative operators such as type coercion and co-composition. These provide GL with a powerful mechanism for sense generation and disambiguation.

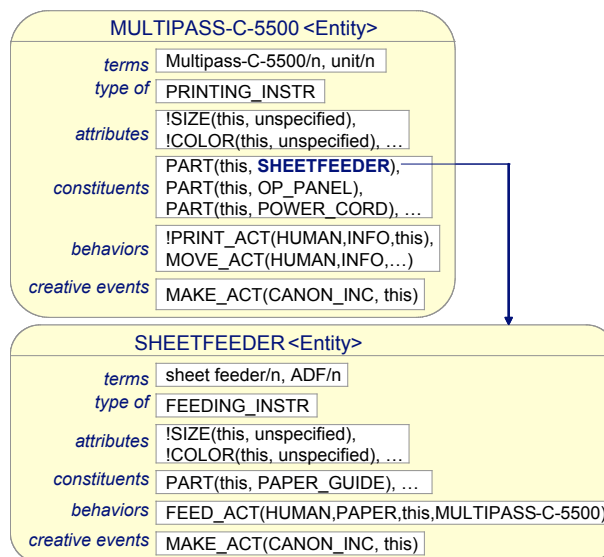


Figure 2: Two GSO-represented concepts.

While theoretically useful, our analysis has revealed that this representation requires several practical extensions, which we describe in (Gupta and Aha 2003). We call our extended representation a *Generative Sublanguage Ontology* (GSO), which uses predicate argument structures in a multiple-inheritance, object-oriented framework with argument bindings. GSOs are distributed, accommodate subjectivity and redundancy, and are minimal. In contrast with GLs, GSOs support morphologic operations (e.g., inflection, derivation), distinguish four primitive concept types (i.e., *entity*, *value*, *state*, and *event*) to constrain and simplify concept representation, and include an extended representation for world knowledge (pragmatics) at appropriate abstraction levels. These features contribute to improving the accuracy and robustness of text interpretation and simplify lexicon engineering tasks (Gupta and Aha 2003).

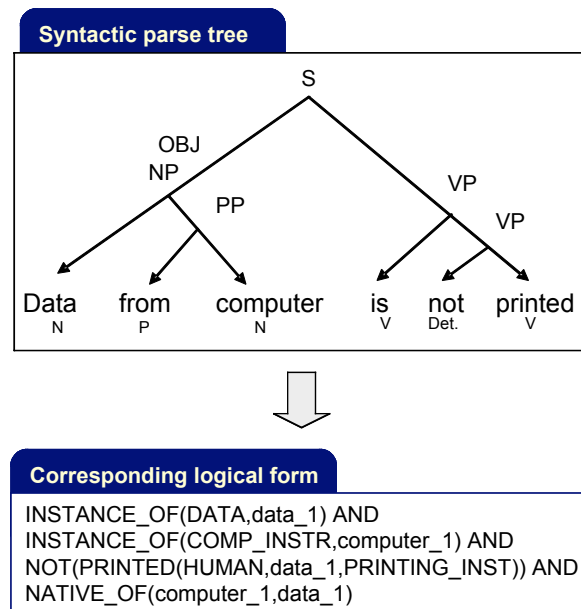
Figure 2 displays two GSO-represented concepts for a Canon Multipass C-5500 printer and its sheetfeeder. Both concepts are represented as entities, and are related in that the sheetfeeder is a part of the printer. Shown are terms for naming these concepts, their type, some common inherited attributes, constituents, behaviors that involve them, and the event that created them.

In summary, GSOs can help to derive canonical concept representations of text sources, thus facilitating interoperability. Furthermore, they make interoperability feasible by reducing the need to update lexicons in dynamic domains, in part by supporting a generative sense-selection process in which they can identify a novel phrase's sense without having previously encountered it. Most importantly, they can be used to help derive a logical form of the text, which we discuss below.



### Step 2: Syntactic parsing:

Using a suitable grammar and a GSO for its lexicon, this step's goal is to assign part-of-speech and identify sentence structure for the given document. We represent sentence structure with a hierarchy of syntactic relationship among its terms. Syntactic structures are generated by syntactic parsers. They are categorized as either *shallow* or *deep*. The former use statistical, memory-based (e.g., Zavrel and Daelemans 1999), and/or data-based techniques to efficiently return one or a few top ranked parses, but they return only constituent phrases and a partial syntactic structure. Using shallow parsing is problematic because the likelihood of finding a valid parse can be unacceptably low. Also, shallow parsing shifts and increases the burden of knowledge engineering to the development of information extraction (IE) patterns, which provide limited domain knowledge and coverage. In contrast, deep parsers search for and enumerate all potential parses. However, this approach can generate numerous parses, thus resulting in considerable sentence structure ambiguity that must be resolved. Although generating all parses can be computationally expensive, this must be done to find a valid parse. For this reason, and because we apply FACIT in an off-line process, we use a deep parsing approach.



**Figure 3:** A syntactic parse and its corresponding logical form.

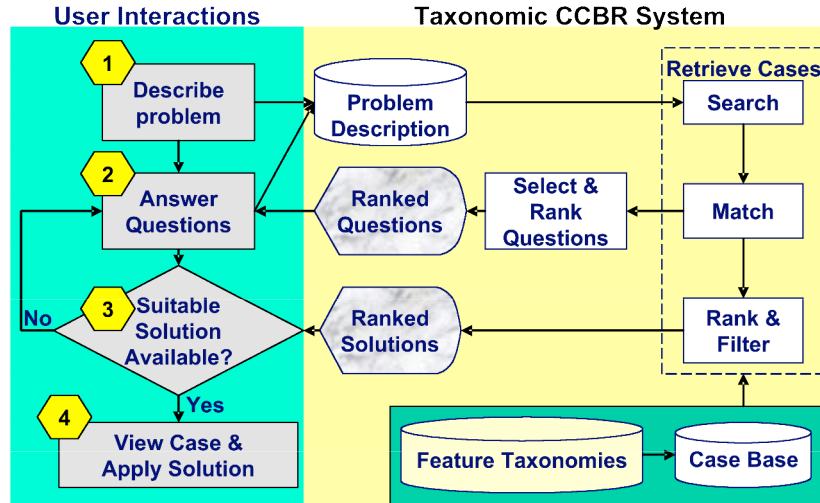
Our domain analysis revealed that military lessons learned text poses particular challenges with their numerous acronyms, abbreviations, and morphological variations of terms. Thus, FACIT performs acronym (and abbreviation) extraction and baseform derivation of given terms. We discuss these briefly in Section 3.

### Step 3: Semantic interpretation:

Semantic interpretation transforms the syntactic parse into a logical form. Figure 3 displays the logical form for the sentence *Data from computer is not printed*. It eliminates syntactic variance (i.e., sentences with different grammatical structure but with the same meaning) by reducing them to the same logical form. For example, the following different sentences can be reduced to the logical form shown in Figure 3:

- Data sent from the printer to the computer is not printed
- Data is not printed by the printer
- Multipass is not printing data from the computer





**Figure 4:** The Taxonomic Conversational Case-Based Reasoning methodology.

Translation of text to its logical form permits the application of predicate calculus operations, thereby enabling the types of symbolic reasoning needed for FACIT's feature extraction and feature organization steps.

FACIT creates a logical form from the syntactic parse using a three-step process. First, using the GSO it retrieves concepts corresponding to senses for the terms in the parse. This makes use of a GSO's representation for predicate argument representations. Second, it resolves semantic ambiguity (i.e., when multiple concepts are retrieved) using a heuristic approach. For example, in the example shown in Figure 3, the term *from(p)* may have multiple meanings, including both OCCUR\_LOCATED and NATIVE\_OF. We assume that the latter meaning is chosen according to a heuristic rule. In its third and final step, FACIT resolves syntactic ambiguity by selecting the parse(s) with maximal predicate argument bindings.

#### Step 4: Feature extraction:

We consider feature as a means to describe a situation. Our approach will involve obtaining training data by asking a subject matter expert to annotate sample sentences as features or non-features. FACIT will use these annotations to induce a classifier, where features are represented in a logical form. We will select an appropriate algorithm for inducing classifiers by analyzing the learning task, and will use the trained classifier to extract features from all the text.

We next define our case representation prior to defining the feature organization and case indexing assignment steps (i.e., Steps 5 and 6) that target it.

#### Step 7: Conversational taxonomic case retrieval:

We focus on a stand-alone lesson retrieval capability, and discuss its integration with other decision support tools in Section 5.

Gupta (2001) introduced a taxonomic extension of the conversational case-based reasoning (CCBR) methodology, which conducts an incremental query elicitation "conversation" with a user to help retrieve relevant case(s). For our lesson retrieval application, these queries can be



matched with lesson case situations. CCBR systems represent cases as <problem, solution> pairs, where problems are represented as a set of <question, answer> pairs, or *features*. Taxonomic CCBR organizes features into a set of taxonomies, where:

- each feature appears in exactly one taxonomy,
- parent nodes *subsume* their children, in that a parent’s feature appears in a superset of the cases in which its children’s features appear, and
- the intersection among two siblings’ cases is empty.

Finally, the only features that are used to index cases are the leaves, and each index for a case must appear in a different taxonomy. Gupta et al. (2002) reported that Taxonomic CCBR outperforms the standard CCBR approach across several performance variables.

Our Taxonomic Case Retrieval System (TCRS) implements this process, which is shown in Figure 4. Users begin a conversation by: (1) entering a problem description (i.e., a *query*) in free text. The system responds by identifying which, if any, of the known features are included in the textual description. This in turn identifies the taxonomies that include the identified features. These taxonomies contribute a set of questions that can be asked for traversing down the taxonomies by one level. TCRS selects, ranks, and displays these questions to the user. (2) The user can answer any of the displayed questions that refine the problem description. Subsequently, the refined problem description is matched with the stored cases and their solutions are displayed in descending order of similarity to the user, who can (3) decide whether to (4) select and view a case for decision making.

#### Step 5: Feature organization:

In FACIT, feature organization concerns the extraction of TCRS taxonomies from a set of given features. We introduced and evaluated a feature organization approach named *TAXIND* in (Gupta et al. 2004). However, *TAXIND* makes the simplifying assumption that features are provided as <question, answer> pairs rather than in logical form. Although this permitted us to quickly develop *TAXIND* and analyze issues in feature organization, this assumption also complicates the process of identifying subsumption relations among features. Thus, while *TAXIND* outperformed a baseline algorithm, its performance leaves much to be desired.

We instead plan to organize features into subsumption taxonomies using the following procedure. First, it will identify feature subsumption relations via a pair-wise comparison of each feature. Logical form expressions can be complex. Therefore, initially we will consider only conjunctive expressions. The lexicon will provide the domain specific knowledge to identify these relations, assessing subsumption using three types of relations (*is-a-type-of*, *constituent*, and *is-a-subevent*). Additional domain knowledge, in the form of implication rules, will be used as needed. For example, the implication rule

$$\text{NOT}(\text{EVENT}) \sqsupset \text{PROBLEM}(\text{EVENT})$$

implies that, if an event does not occur, then there is a problem with the event. Thus, we can conclude that the statement “printing Problem” subsumes the statement “Data from computer is not printed”. To assess this subsumption relation, our procedure will generalize the logical form of the statement “Data from computer is not printed” by reducing the conjuncts to



NOT(PRINTED(HUMAN,DATA,PRINTING\_INST)) and then applying the rule shown above to obtain the further generalization PROBLEM(PRINT\_EVENT), which is a logical form for the statement “Printing problem”.

After all potential subsumption relations are identified, directed graphs, each representing a taxonomy, will be automatically constructed and presented to the domain expert for verification.

#### Step 6: Case index assignment:

Indexing a taxonomic case involves assigning features that are leaves from distinct taxonomies. Using the logical form of features and the feature taxonomies as a reference, FACIT will select only the most specific distinct features applicable to a case to encode it. If a most specific feature in the case is not a leaf from one of the taxonomies, then the case shall be brought to a domain expert’s attention for review and refinement.

### **3.2. Implementation status**

A complete implementation of FACIT requires a significant development effort. Table 2 summarizes FACIT’s implementation status, identifying both planned and implemented components. We describe these with respect to the FACIT step that they address.

We have developed software tools that support the development and maintenance of GSOs, including the Concept Discovery Workbench, which supports the semi-automatic acquisition of concepts from text documents, and the GSO Editor, which allows users to edit new and existing concepts. These greatly simplify and accelerate the development and maintenance of generative sublanguage ontologies. Also, we have developed and evaluated the Acronym Extractor (AcE), an automated tool for identifying and extracting acronyms and their expansions (Gupta and Aha 2004a). AcE is a domain independent extraction system that can be customized to a specific domain by adding a suitable domain dictionary. Our empirical comparisons showed that AcE performs as well as or better than two other systems. However, we have not yet implemented the GSO Learning Workbench, which will assist us with updating the GSO automatically.

We have implemented an interface to the Link Parser (Link 2004) to perform syntactic parsing. It degrades gracefully when presented with ill-formed text by allowing broken links or structures. We then integrated this with Brill’s (1992) part-of-speech tagger to help efficiently select better parses. We have also integrated these tools with AcE and RuMoP (Gupta and Aha 2004b), a morphotactic parser that reduces inflected and derived terms to their baseforms for subsequent lookup in our semantic lexicon.

We are currently implementing a preliminary version of a semantic interpreter (SemLink) that will operate with our GSO representation and the output of the syntactic parser. However, this is limited, and our future work includes developing a morpho-semantic interpreter to derive the meanings of morphological inflections and derivations.



**Table 2:** Planned and implemented FACIT components.

FACIT Step	Component	Complete?
<b>1. Lexicon Engineering</b>	Concept Discovery Workbench	P
	Acronym Extractor	P
	GSO Editor	P
	GSO Learning Workbench	
<b>2. Syntactic Parsing</b>	JLINK Syntactic Parser	P
	JB Brill Part-of-speech Tagger	P
	Acronym Extractor	P
	RuMoP Morphotactic Parser	P
<b>3. Semantic Interpretation</b>	SemLink	P
	Morpho-semantic Interpreter	
<b>4. Feature Extraction</b>	Feature Extractor	
<b>5. Feature Organization</b>	TAXIND (v1)	P
	TAXIND (v2)	
<b>6. Case Index Assignment</b>	Index Assigner	
<b>7. Taxonomic Conversational Case Retrieval</b>	Taxonomic Case Retrieval System (TCRS)	P

We have not yet implemented a feature extraction algorithm; it will interact with the user to identify features of interest. No case index assignment module currently exists, either, although its implementation is expected to be straightforward. As mentioned in Section 3, an initial version of a feature organizer, TAXIND, exists. However, it was intended only as a placeholder, and we plan to develop a variant that inputs features in logical form.

Finally, TCRS is a relatively mature tool. We have demonstrated that it performs better than the standard CCBP approach on several performance measures (Gupta et al. 2002).

#### 4.3. Related Work

At this time, we are not aware of any other practical implementations of generative lexicon theory.

FACIT performs knowledge extraction (KE) (Cowie and Lehnert 1996), which differs from information extraction (IE) in at least four respects. First, KE focuses on the extraction of categories (e.g., rules, models) rather than instances (e.g., addresses, menus). Second, KE must use deep natural language interpretation process to accurately identify the subtleties in meaning required for acceptable extraction performance. In contrast, IE approaches effectively employ shallow parsing techniques along with extraction patterns where subtleties of meaning do not have a significant impact on extraction performance. Third, KE relies on only a few extraction patterns with semantic classes and logical forms as triggers, whereas traditional IE employs a large library of domain specific patterns with terms and phrases as triggers. Finally, KE approaches use a rich ontological representation for text interpretation, a step that is typically bypassed in traditional IE systems. Instead traditional IE systems directly apply patterns to shallow parsed text for extraction. However, traditional IE performance is sensitive to authoring styles and the coverage of shallow extraction patterns, thereby creating a pattern maintenance



problem. FACIT reduces this problem by relying on semantic interpretation and less on extraction patterns. It effectively reduces feature engineering effort, and will likely yield systems that have higher recall and precision performance than shallow NLP approaches in situations where the characterizing features are not known a priori.

In (Gupta et al. 2004), we compared and contrasted FACIT with other approaches for acquiring case indices from text documents. Few if any related approaches exist. For example, SMILE (Brüninghaus and Ashley 1999), an approach for case indexing, only performs index assignment based on a predefined feature set. In contrast, FACIT also performs feature extraction. Hence, it is more suited to dynamic domains. Furthermore, FACIT's indexing strategy differs greatly from other approaches that acquire indices for cases used in a case-based reasoning methodology.

#### **5.4. Future Work**

Section 3 outlined several of our future implementation tasks, which must be completed prior to evaluating FACIT empirically. Although we have evaluated several of its components (e.g., AcE, RuMoP, TAXIND, TCRS), a complete evaluation will differ substantially in that it will require interaction with subject matter experts (for Steps 4-6) and users (Step 7). We plan to assess its utility on a range of both user and system performance measures. In addition, while our first performance task concerns lesson document retrieval, we also plan to assess FACIT's knowledge extraction performance for other decision support tasks (e.g., plan extraction from text documents).

FACIT is a knowledge intensive framework; it benefits from extending an initial linguistic ontology, and uses rule sets for both semantic interpretation and feature organization. Additional uses of domain specific knowledge may also emerge when we apply FACIT to other tasks. Thus, we will investigate approaches for decreasing knowledge acquisition costs for the lexicon, rule sets, and other information sources.

#### **6.5. Conclusion**

Interoperable systems require representations that are suitable for sharing information among their agents, and decision support tools are no exception. These tools are frequently provided with domain specific information as a result of a tedious manual knowledge engineering process, often involving the encoding of information obtained from text sources. We described the FACIT knowledge extraction framework and its promise for reducing such knowledge engineering efforts. FACIT employs generative sublanguage ontologies to support the semantic interpretation of text documents and subsequent feature organization tasks. This representation for linguistic knowledge has several benefits versus existing approaches, and can be a cornerstone of interoperable agent-based systems.

However, to our knowledge, there are no implementations of generative linguistic ontologies, other than our own. Furthermore, FACIT's performance task is challenging, and requires extensive development effort. We have implemented several of its modules, but several more require implementation. This effort seems particularly worthwhile, and should yield a robust and domain independent approach for interpreting text documents. FACIT yields a computable,



conceptual representation of its source documents. Thus, after its implementation is complete, we anticipate applying it to many domains and tasks of interest.

## Acknowledgements

This work was supported by the Naval Research Laboratory. Thanks to Jens Pohl and Michael Zang for encouraging our participation at the 2004 CADRC/ONR Workshop on Collaborative Decision-Support Systems.

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# Semantic Mediation Tools for Interoperability

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6<sup>th</sup> Annual ONR Workshop on Interoperability – 8<sup>th</sup> September '04  
Quantico Marine Corps Base, Quantico, VA.



## Outline

- Motivation
- Pragati Tool Suite Overview
- MVP-CA Technology Core
- IOD Overview (NASA SBIR)
- CODE Plug-In Overview (DOD/IHMC)
- OSRT Overview (ONR SBIR)
- Conclusion



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## Ontologies Enable Interoperability

### *An ontology is*

- Set of concepts used in a particular domain of discourse
- Interrelationships between the concepts
  - behavioral characteristics
  - operational characteristics
- Ontologies provide a framework for expressing a **common lingua** to be utilized across systems
- Expressing semantics of concepts **formally** through ontologies enables automated reasoning, desired functionalities and collaboration across systems



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## Ontological Design Principles

Ontological engineers try to optimize the ontological design

- Parsimonious design of concept classes
- Crispness in the distinctions across concepts
- Richness in the associations across concepts



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## Ontological Concerns

- Information overload is occurring in the creation of ontologies
- Every organization "thinks" their "core ontology" will be the Holy Grail for ontologies
- Reality #1: The notion of a canonical ontology is, at least at present, a myth
- Reality #2: We currently have to live with a cloud of candidate ontologies which model a "real" concept from different perspectives

### *Ontology Developer's Dilemma:*

*How can I effectively find and reuse concepts from that "cloud"?*



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## Vision

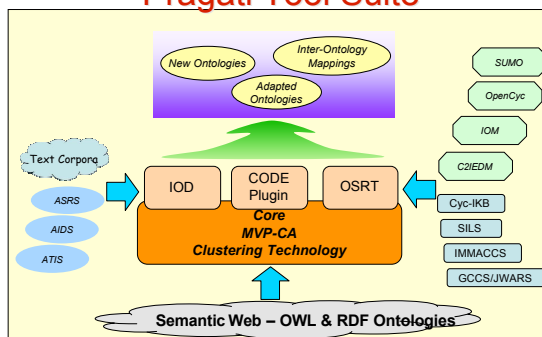
### *Build semantic mediation tools to aid*

- **Identification** of similar patterns across ontologies and information systems
- **Construction** of ontologies through information extraction from such systems
- **Searching** for concepts in ontologies and KBS
- **Evaluate** potential for reuse
- **Mapping & alignment** of concepts across ontologies
- **Reuse** of concepts through adaptation & merging
- **Maintenance** of Ontologies and KBS
  - Comprehension
  - Verification & Validation



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## Pragati Tool Suite



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## Core technology

## MultiViewpoint Clustering Analysis (MVP-CA)

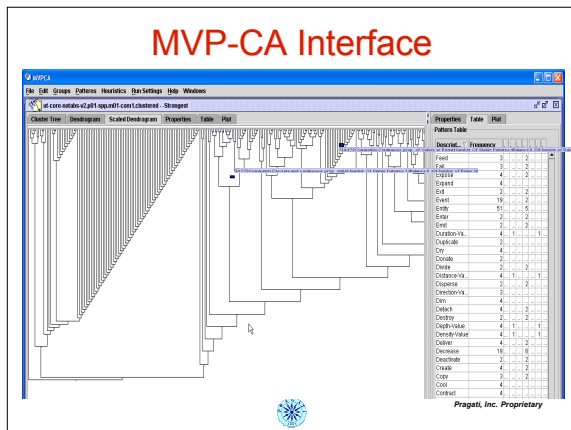


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**Approach:**  
*Cluster a knowledge base from multiple perspectives*

- Clustering of knowledge bases into groups of semantically-related rules/axioms reveals
  - Relationship of terms in the context of their usage
  - Prototypical patterns of usage for the terms in the axioms
- Multiple ways of clustering (based on different objective criteria) aid in understanding and analyzing KBs from different perspectives




# IOD Problem Statement

- Data and knowledge repositories contain
  - Large amounts of unstructured but
  - Stylized natural language text
- Simple text-based search techniques successful in retrieving somewhat relevant documents to a human analyst's needs,
- Information contained in those documents is opaque with respect to
  - query
  - manipulation
  - reasoning tools
  - semantic content of the text

## Proposed Solution

Extract semantic content from the text  
and  
capture it in an **ontology**

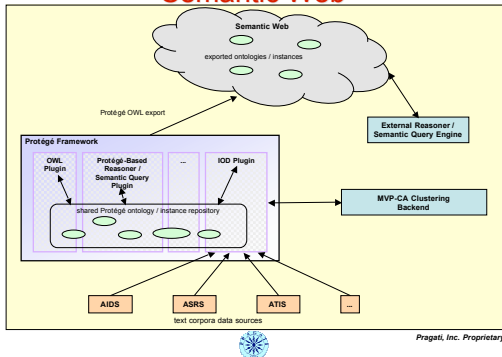


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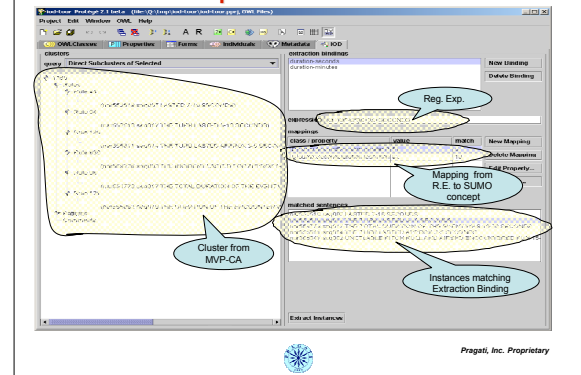
- Analyze the data set to generate sub-sets with related concepts/similar concepts **MVP-CA**
- Generate a regular expression to capture the similarity pattern **IOD**
- Map the regular expression to an ontology fragment consisting of concepts from existing ontologies along with new concepts **IOD and Protégé**
- Use the extraction binding (regular expression and the mappings) to extract new instances from the data set **IOD and Protégé**



## Data-Flow between IOD, Protégé, & Semantic Web



## Mock-up of IOD Interface



## Enable the Protégé/OWL Query Model

Use a candidate OWL reasoning system such as JTP or RACER:

Query: "What is the mean duration of reported turbulence events?"

Answer: "a mean lower bound of 4 seconds, and a mean upper bound of 7.5 seconds."



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## Collaborative Ontology Development Environment (CODE)-Plug-In



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## CODE Environment (Institute for Human & Machine Cognition (IHMC))

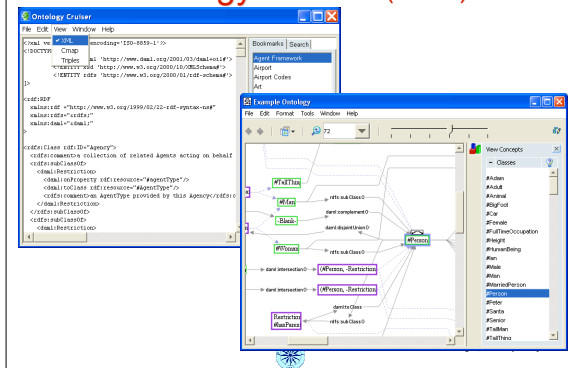
A Collaborative Environment for  
Viewing, Searching and Developing Ontologies

- **Ontology Viewer** –
  - Transforms DAML ontologies (written in RDF, OWL, etc.) into "natural" CMAPs
  - Suppresses mundane/obvious information
  - Determines graph layout to show CMAPs
- **Ontology Search – Cruiser**
  - Searches ontologies locally & on web
  - Mechanisms to bookmark ontologies
  - Support for searching for concepts in these ontologies
- **Ontology Development**
  - Drag & drop support for incorporating concepts in existing ontologies
  - CMAP tools for graphical editing of concepts
  - Transformation tools from CMAP to XML/RDF/DAML/OWL format
  - Real-time collaboration aids for geographically distributed groups



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## Ontology Cruiser (IHMC)





## Issues in the Cruiser

- No semantic underpinnings for searching of concepts
- No cross ontology awareness
  - Zoom-in feature unable to place the concept in the broader context
- Information overload when searching for relevant concepts
- No indication of relevance ranking in the retrieved ontologies
  - For example, culture (sociological aspect vs. biological experiment)
- Denseness of CMAP representation despite suppression of mundane information in the RDF concept descriptions



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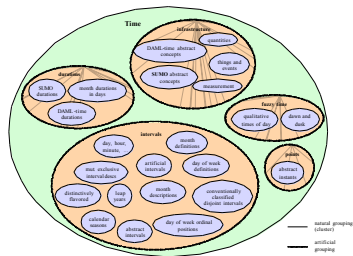
## MVP-CA based Plug-In for CODE

- Given a concept extract similar concepts from across a wide range of Semantic Web (OWL) ontologies using a variety of matching criteria
- Rank the matching concepts based on a variety of relevance measures
- Present the relevant matching concepts in the context of the source ontology along with the vicinity concepts
- Also, utilize MVP-CA clusters as a starting point for rendering of CMAPs so as to simplify their presentation



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## Multiple-Ontologies Time Clusters



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## Time Clusters across SUMO & DAML Ontologies

<http://reliant.tekknowledge.com/DAML-Time/SUMO.owl#TimePosition>  
<http://reliant.tekknowledge.com/DAML-Time/SUMO.owl#TimeMeasure>  
<http://reliant.tekknowledge.com/DAML-Time/SUMO.owl#TimeDuration>  
<http://reliant.tekknowledge.com/DAML-Time/SUMO.owl#TimeInterval>  
<http://reliant.tekknowledge.com/DAML-Time/SUMO.owl#TimePoint>

<http://www.isi.edu/~pan/damtime/time.owl#TemporalEntityCollection>  
<http://www.isi.edu/~pan/damtime/time.owl#MetaTemporalEntityClass>  
<http://www.isi.edu/~pan/damtime/time.owl#Instant>  
<http://www.isi.edu/~pan/damtime/time.owl#Interval>  
<http://www.isi.edu/~pan/damtime/time.owl#MetaTemporalThingClass>  
<http://www.w3.org/2002/07/owl#Class>  
<http://www.isi.edu/~pan/damtime/time.owl#TSeq>  
<http://www.isi.edu/~pan/damtime/time.owl#TemporalThing>  
<http://www.isi.edu/~pan/damtime/time.owl#TimeSpanClass>



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## Ontology Search & Reuse Tool (OSRT)



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## OSRT Vision

A tool that enables builders of knowledge-based systems to *identify and reuse* relevant portions of existing systems, thereby

- Reducing development time
- Amortizing development costs
- Enhancing quality of developed system

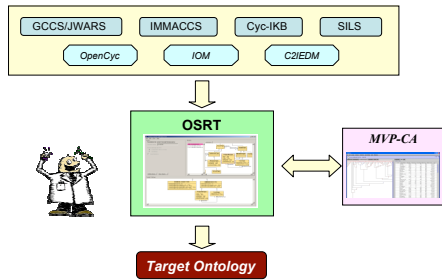
**overall increase in return on investment (ROI)**



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## Ontology Search and Reuse Tool



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## Ontology Developer's Dilemma

- Where is the concept?
  - Searching for the relevant concept
- How is it used?
  - Concept perspectives based on context of usage
- How to adapt it?
  - Concept transformation and merging



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## Queries

- **Semantically Rich Queries**
  - Concept Name
  - Attribute Name
  - Generalization Structure
  - Association Relationship
  - Vicinity Concept
- **Repertoire of String Matching Algorithms**
  - Component Vector Overlap
  - Substring Matching
- **Query Plug-In support**
  - To allow new types of queries to be easily integrated into the framework



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## Concept Usage Views

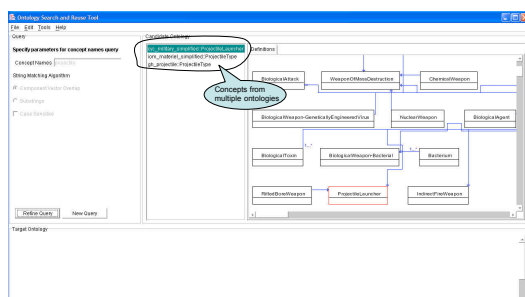
### Cognitive Aids for Concept Selection

- **Definitions View**
  - Displays the focus concept as declared in the ontological hierarchy through Embarcadero Describe's XML export
- **Vicinity Concepts View**
  - Displays the vicinity concepts – concepts that co-occur with the focus concept
- **Rules Usage View**
  - Displays the cluster of rules where the focus concept has localized
- **Templates View**
  - Displays the templates associated with the cluster of rules



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## Query Based on Concept Name



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## Ontological Issues

### Conceptual/Modeling Differences

- **Level of Abstraction**
  - Concepts are too specialized  
Example: *Ford Taurus, Toyota Camry, Honda Accord*  
=> *Automobiles*
  - Concept is too general:  
Example: *Move* =>  
*Move-Into, Move-To, Move-Out-Of, Move-Through*
- **Placement in the ontological hierarchy**  
Different choices on specifying ontological distinctions for orthogonal characteristics  
Example: An ontology for organizing clothes line is different for
  - (a) department store layout for customers  
*Gender (mens', womens')*
  - (b) ordering clothes from a manufacturer  
*Clothes-type (pants, shirts)*



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[illegible]

# Ontological Issues

## Term Relationships

- **Vicinity Terms** – Terms related via common usage patterns  
Example: **Pour, Immerse, Permeate**
- **Complementary/Inverse terms**  
Example: **Move-From & Move-To, Exit and Enter**
- **Homonym Terms** - Context determines the semantics  
Example: **Contract** -> physical change vs. legal document  
**Culture** -> societal issues vs. biological experiment
- **Overloaded Terms** – Same semantics for very different contexts  
Example: **ObjectFoundInLocation**



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# Rules View

Pragma IDE Rules View

Query

Specify parameters for locally constructed query

How Concept Names are Interpreted

Stop Matching Algorithm

Case Sensitive (checked)

Case Insensitive

Validation Output

Rule 42

Rule 100

Rule 101

Rule 102

Rule 103

Rule 104

Rule 105

Rule 106

Rule 107

Rule 108

Rule 109

Rule 110

Rule 111

Rule 112

Rule 113

Rule 114

Rule 115

Rule 116

Rule 117

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Rule 445

Rule 446

# Ontological Issues

*Term-conceptualization and Term-explication Differences*

- Lexically and semantically close terms


*Example: **Move & Move-Into,**  
**Touches & TouchesDirectly**  
**Prevent & Prevents***

- Lexically distant but semantically close terms

*Example: **providesCoverInCOA & providesConcealmentInCOA**  
**TaskTypeRequiresAgentType, opTypeRequiresAgentType***

- Lexically reversed but semantically close terms

*Example: **ForwardPassageOfLines-MilitaryOperation &**  
**PassageOfLines-Forward-MilitaryTask***




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# Templates View

# Mapping Aids

- Support for mapping of terms across ontologies can be provided by flagging terms that are used in **similar contexts or similar behavior pattern**
- Such similarities can be extracted using the same technology as used for *template formulation* when applied across different ontologies



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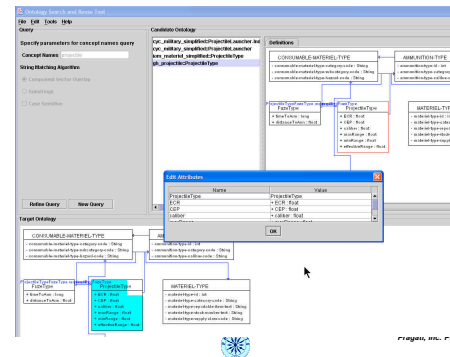
## Adaptation Support

- **Concept Adaptation**
  - Copy and paste into target ontology
  - Edit concept attributes and relationships
  - Merge with concepts in the target ontology
- **Rules Adaptation**
  - Display MVP-CA generated templates in OSRT



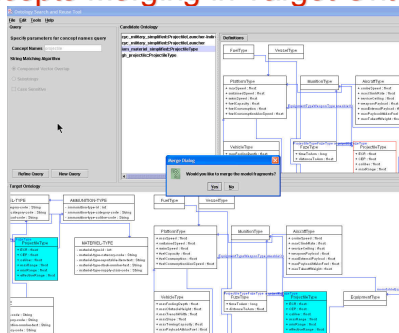
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## Concept Adaptation in Target Ontology



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## Concepts Merging in Target Ontology



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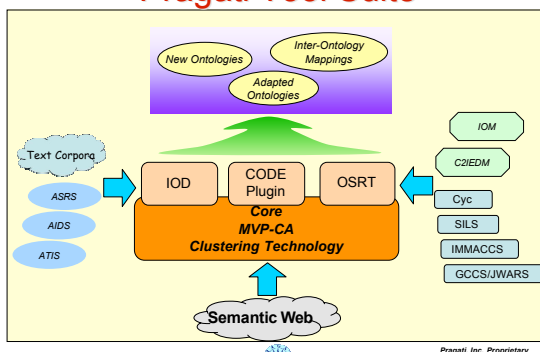
## Envisioned Extensions to OSRT

- Extend OSRT's reuse model to automatically generate mappings based on the user's reuse directives.
- Design a framework to map instances between distinct, but semantically overlapping, ontologies.
- Implement import/export plugins appropriate to the specific ontology, instance, and mapping representations used by the host system.



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## Pragati Tool Suite



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## Uniqueness of Overall Approach

- Allows subtle, semantically-oriented analysis of ontologies
- Pattern-based approach for clustering
  - discovers pattern-conforming/non-conforming regions in KB
- Clustering in similarity space (instead of feature space)
  - Reveals higher-level information on relationships across concepts
- Clustering axioms is based on usage of axioms (independent of the declared ontology)
  - Reveals information of tacit nature not captured in the ontology
- Domain and representation-independent
  - Allows flexibility in deploying technology to any semi-structured information system



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## Benefits

- Cost-Effective Solution for Building and Organizing Ontologies & KBs
  - Less time needed
  - Less personnel needed
  - Effective reuse of legacy systems
- Quality Solution enabling high-end analysis for
  - Development
  - Maintenance
  - Interoperability
- Adaptive Solution to Changing Demands
  - In time as ontologies evolve across applications
  - In perspective for different types of users



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# **Challenging Old Assumptions in Global Information Management**

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## **INTRODUCTION**

Many fundamental assumptions in information management are driven by the nature of problems in the business world, and by the kinds of technology that have been available. The distinctive nature of combat, and new technical developments, invalidate some of these assumptions. This paper discusses three of these assumptions:

- That users need access to everything;
- That the Global Information Grid (GIG) needs a global semantic standard;
- That information is passive (and only people are active).

It explains why each assumption is invalid, and outlines emerging technologies that suggest new directions for addressing the needs that these assumptions identify.

## **ASSUMPTION 1: UNIVERSAL ACCESS**

The vision behind the “common operational picture” (COP) is that information technology will enable every user to have access to any piece of desired information, and that this information will be consistent across all users.

There is no question that many users *want* access to all information, at least in principle. However, actually delivering such access may be technically intractable and psychologically undesirable, and new research is pointing the way toward mechanisms that will enable information systems to select the best information to send to each user.

### ***Why is Universal Access Inachievable?***

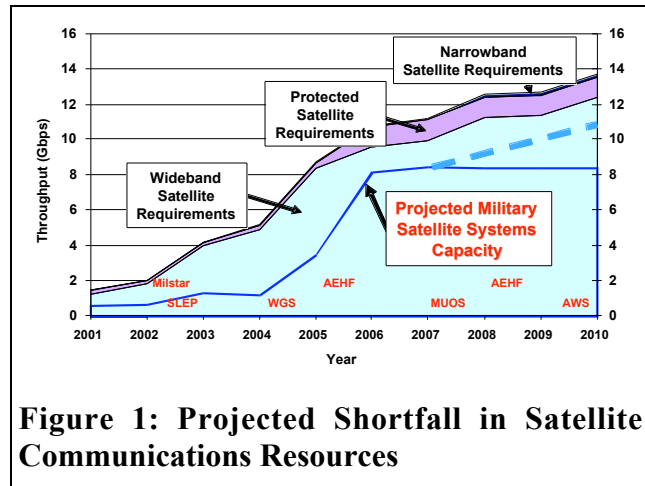
The vision of making all information available to all users faces two fundamental limits, one psychological and the other technical.

Psychologically, there is a limit to the amount of information that a human being can process. This limit is illustrated every time someone searches the World Wide Web using a search engine such as Google. These searches routinely return tens of thousands of results, but most users consult only the first few links on the first page.

This anecdotal experience is borne out by two lines of research. The cognitive limitations of the human organism were highlighted nearly fifty years ago in George Miller’s classic study, “The



Magic Number Seven, Plus or Minus Two” [3]. Reviewing a broad range of psychological studies, he found a sharp decrease in performance when people were asked to manipulate more than about seven items of information concurrently, reflecting the intrinsic limits of human attention. More recently, studies in artificial life [5] show that as an agent’s knowledge of its environment grows, its performance first increases, then decreases as its sensors become overloaded. Both results suggest that an important function of an information system is striking a balance between the amount of information available and the capacity of the human to process it.



**Figure 1: Projected Shortfall in Satellite Communications Resources**

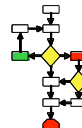

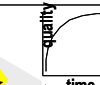
There is also a technical limitation to global information access. It is sometimes assumed that steady technical progress in telecommunications will eliminate any constraint on bandwidth, and in the abstract, great gains are being made in our ability to move information around. Practically, though, it is unlikely that this technology will be available to operators in the field in a reasonable time frame. Figure 1 summarizes a recent study by the Office of Net Assessment [1] on the availability of commercial and planned military satellite communications resources that could be used in case of military emergency, compared with projected needs. Commercial providers have moved away from satellites and toward fiber for their backbones. While satellites could support military communications in areas far removed from those they were originally intended to support, new fiber is tied to specific regions, and is not available to support conflicts in (say), the empty quarter of Iraq.

Thus, fundamental limitations in both human and technical capacity make it unwise to plan an information system around the assumption that every user can in principle have access to all information.

## What is the Alternative to Universal Access?

If we cannot provide all information to every user, we must be selective, filtering the available information to match the user’s needs. Two basic approaches are available: deterministic and stochastic filtering (Figure 2).

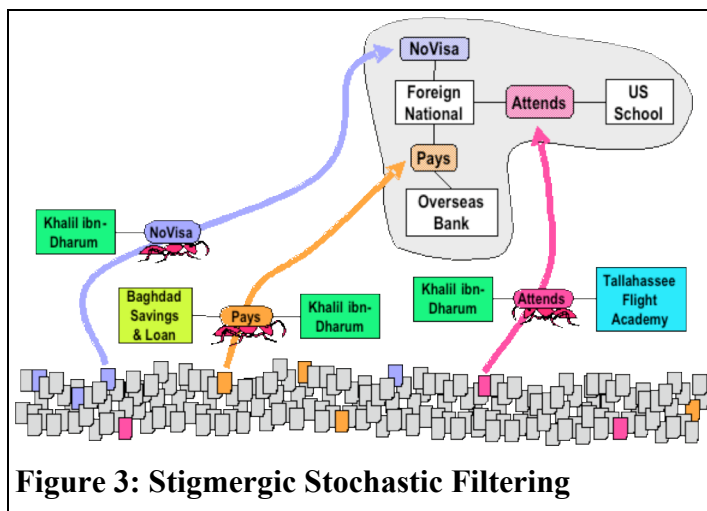
*Deterministic filtering* uses a formal logical analysis (often based on symbolic artificial intelligence) to match the user’s interests against available information and select the information that is most likely to be relevant. This approach is attractive because the user can understand the logical rules used to select the relevant

Deterministic	Stochastic
	
<p>“NP-Hard”: as size of problem grows beyond toy examples, the processing approaches the age of the universe (or longer!)</p> <p>Time to solution grows exponentially with size</p> 	<p>“Weighted Monte -Carlo”: Select randomly, Guided by self-organizing mechanisms inspired by natural insect colonies (“stigmergy”)</p> <p>Quality of solution improves exponentially with time</p> 

**Figure 2: Two Approaches to Filtering Information**



information, and thus gain confidence that the system will deliver the required material. Unfortunately, as the volume of available information grows, this confidence can be disappointed, because of the computational complexity of the processing involved. It is intuitive that as the amount of information that needs to be reviewed increases, the time necessary to review it will increase as well. If the processing time increases as a polynomial of the size



**Figure 3: Stigmergic Stochastic Filtering**

of the input, it is reasonable to rely on more powerful computers, or larger number of computers, to meet the challenges of expanding information. However, deterministic logical methods, especially those that confront realistic representations of semantic structure, tend to be NP-hard. That is, the length of time required to execute the logic increases exponentially in the length of the input, and problems that are larger than toy examples will not be able to complete in a reasonable length of time even on the fastest computers we can imagine.

Deterministic filtering is intractable, but *stochastic filtering* is not. In its simplest form, stochastic filtering simply means that we select randomly from the available information. Purely random selection is unlikely to provide any information that is relevant to the user's interests, but it is possible to weight the selection in such a way that the retrieved information is more likely to be relevant to the user's interests. We have been developing mechanisms for stochastic filtering, inspired by the mechanisms that insects use to sort their nests and coordinate their actions [6]. These mechanisms, known collectively as "stigmergy," use the environment in which insects live as a locally indexed communication mechanism [4]. In this approach (Figure 3), digital ants *swarm* over a massive collection of documents, *recognize* fragments of a concept map that represents the user's interests, and *self-organize* to populate the map with documents relevant to its underlying assumptions. Stigmergic mechanisms have several desirable features.

- For many such processes, the quality of the solution (for example, the number of relevant documents retrieved) increases exponentially over time. That is, initially the number of documents grows very rapidly, providing an initial basis for the user's decisions. If the user has longer to wait, the process will continue to yield improved results, although at a slower rate.
- The process can easily be distributed over many machines, without the need for central coordination.
- The process continues to operate even in the face of dynamic change (for instance, shifts in the user's interests or in the body of information available), without the need to be restarted.



## ASSUMPTION 2: GLOBAL SEMANTIC STANDARD

One of the greatest contributions of the Internet has been to lower the walls separating different bodies of information. Information that twenty years ago required a trip to the library can now be accessed by a few keystrokes from one's desk. Many different information producers have eagerly made their resources available, in a move toward a single global information grid, or GIG.

Unfortunately, we have learned that exchanging the *form* of information is much simpler than exchanging its *meaning*. Any body of information rests on an assumed way of conceptualizing the world, called an "ontology." For example, people who talk about automobiles agree in advance that a car consists of a body, a power system, wheels and suspension, and an interior, and that options for power systems include gasoline, diesel, natural gas, electric, and hybrid, while veterinarians concerned with horses focus on legs and hooves, hair and skin, and internal organs.

Experience has shown that there is no single "right" ontology for describing the world. Different information producers tend to have different ontologies, making it difficult to combine their information in a single application. A traditional way to deal with this divergence is to attempt to outlaw it, by developing a single ontology that all producers agree to use. This approach is impractical. Fortunately, new technical tools are making it possible to combine information from systems with globally incompatible ontologies.

### ***Why is a Global Semantic Standard Impractical?***

There are three obstacles to the vision of a single global semantic standard: the existence of established inconsistent ontologies, the complexities of translation, and the fact of continuous, rapid change in local contexts.

First, there are many established communities of practice, each with its established view of the world that makes its own activities efficient and internally coherent. As valuable as a global standard may be for people who work across different communities, it will impose severe costs on the existing ontologies that it displaces, costs that are often high enough to dissuade the users of existing systems from abandoning them.

One might hope that an automatic mechanism could be found to translate automatically among different ontologies, thus permitting people to use their existing systems while keeping them aligned to the global standard. The second obstacle to a global semantic standard is that the problem of aligning ontologies belongs to the class of NP-hard problems described in the previous section [2]. That is, for ontologies of realistic size, a program to align them with one another would not be able to deliver results in reasonable time.

The third obstacle is that ontologies are not static. They are constantly evolving to support the needs of the communities that use them. In a dynamic environment (such as the US military in a time of transformation), there will be strong pressures on local groups to specialize or refine the portions of the ontology that they use the most. If a global ontology outlaws such specializations, it will severely limit the productivity of its users; if it does not, it will soon become irrelevant.

The fundamental issue is that thought is dynamic, constantly exploring new combinations and relationships. Any attempt to codify the infrastructure of thought runs the risk of limiting creativity and mental productivity.



### What is the Alternative to a Global Semantic Standard?

It is a fact of ontological life that the overall semantic structures underlying different systems will differ from one another. Instead of trying to impose a global standard, an alternative approach recognizes that most processes that cross

systems require agreement only in a local region of the ontology. Figure 4 illustrates this graphically. Even though the two structures diverge from one another, they are aligned in a local region, and as long as the interactions between them affect only this region, the more remote differences have little impact.

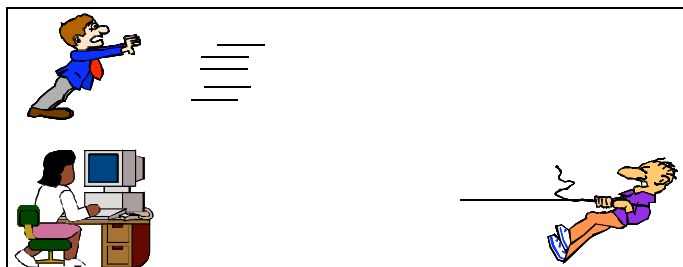
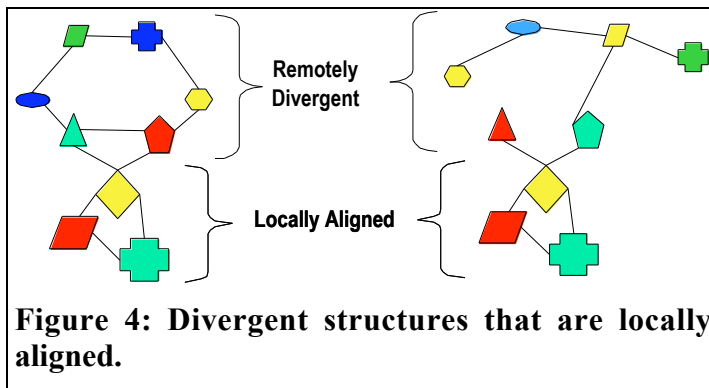
Altarum's Living Ontologies technology supports this alternative approach by enabling knowledge workers (for example, system modelers) to integrate different ontologies in their activities. The technology supports several processes that can be interleaved with one another.

- Modelers can *search* existing ontologies for concepts and substructures that are candidates for concepts that they need to represent.
- They can *compare* these candidates with one another and with new constructs to assess the degree of consistency among them, thus promoting agreement where possible without imposing a single global standard.
- They can then *construct* new systems by combining the candidate structures they have retrieved and evaluated, all the while monitoring the growing model for its consistency with existing structures.

### ASSUMPTION 3: PASSIVE INFORMATION

Before the computer era, information took the form of ink on paper. It was completely passive, and depended on people to file it, retrieve it, transport it, interpret it, and act on it.

In many ways, computer systems have simply automated this view of information. The database or web server has replaced the filing cabinet or library, and email has taken the place of physical couriers, but people still must make the decisions and take the actions to manipulate knowledge. In the email model (Figure 5, top), the current holder of information must know who would find it useful and send it there. In the web model (Figure 5, bottom), someone who needs information must know where it is, and retrieve it. In both cases, information is passive, and all decisions about it must be made by people.





## Why is Passive Information Undesirable?

Passive information was the only option in the days of ink on paper. Today, the line between data and process is extremely fuzzy. Both consist of a machine-readable list of ones and zeroes, and there is no intrinsic reason why one (the process) should be active while the other (the information) is passive. We can imagine an architecture in which each packet of information is self-conscious about its contents and is actively seeking users who might find it valuable (Figure 6). There are two reasons to pursue such a vision of active information.

First, as we have already noted, the cognitive burden on users is increasing as the amount of information available continues to grow. Anything we can do to reduce this cognitive burden will make information systems more effective.

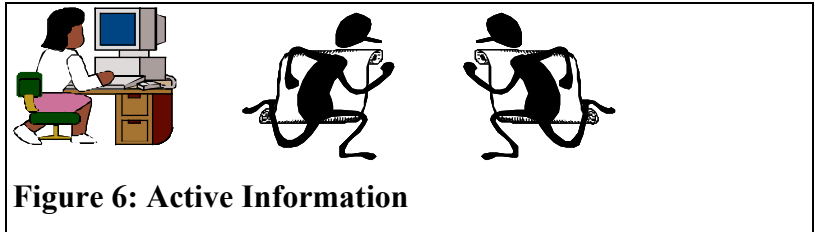


Figure 6: Active Information

Second, the passive information model (Figure 5) forces a rigid and often unrealistic distinction between the *producers* of information, who need to identify possible users to whom they can send reports, and the *consumers* of information, who need to locate likely sources to which they can send queries. This distinction is often inappropriate. Most people who are seeking information, do so in order to support their own information production tasks.

## What is the Alternative to Passive Information?

Altarum has developed an alternative to passive information known as PARTNER (Population of Agents for Real-Time Networking with Emergent Routing). A PARTNER system has three species of agents.

1. *Domain agents* produce and consumer information. They may be people, on-line sensors, legacy databases, or similar entities.
2. *Message agents* are packets of information that circulate in the network. A message agent is neither a query nor a report, but a packet containing some known details and a description of some unknown details that could naturally be related to the known details. Its mission in life is to find other message agents that complement its own knowledge, and bring them to the attention of domain agents whom it knows and who might be interested in information related to its own contents.
3. *Network agents* are the computers that populate the network. They provide three services to the message agents. Like routers in any communications system, they move them around and store them when they are not moving. In addition, they provide processing resources that message agents can use to compare themselves with one another.

PARTNER agents perceive, react to, and reinforce two fields in their environment, simultaneously coordinating their activities and controlling the use of resources (Table 1). A *semantic* field imitates the use of pheromones in insect societies, and guides mutually relevant messages toward each other through the network. An *economic* field, modeled on naturally occurring markets, helps messages use network resources responsibly as they travel.



The semantic field is based on a *signature* that can be associated with any agent, and used to assess its similarity with other agents. The data in a signature can be either explicit (the role and ID of a domain agent; metadata associated with a message agent; the location, capacity, and connectivity of a network agent) or derived (a keyword or concept vector, the texture of an image). These examples can all be precomputed, but signatures can also contain dynamic information developed during the lifetime of a message agent, such as profiles of what users have found a given item interesting.

**Table 1: Two fields drive PARTNER.**

<b>Enabling Flow Field:</b>	Semantic	Economic
<b>Challenge:</b>	Effectiveness	Efficiency
<b>Manages message ...</b>	Relevance	Cost
<b>PARTNER Mechanism:</b>	Digital Pheromones	Budgets

A message's sender initializes its behavior in these two fields, assigning its contents (thus initializing its signature and determining its semantic behavior) and its budget (determining its economic behavior). Network agents maintain the two fields based on the messages they handle. Message agents move through the network, leaving traces of their signature on the nodes through which they pass, and following such traces to find other similar messages. When two message agents with similar signatures meet, they compare themselves, and if they are indeed similar, they notify the domain agents who originated them. If the match produces useful information, the domain agents pay the message agents a reward, increasing their budgets. At the same time, every action that a message agent takes (moving from one network agent to another, occupying storage, comparing itself with other message agents) decrements its budget. Message agents whose budget reaches zero are removed from the system, thus preventing congestion.

Such an information ecosystem has several useful global behaviors.

- The lifetime of information in the system is not fixed by policy, but emerges dynamically, based on the initial budget and the subsequent rewards that domain agents pay to each message agent. Information that proves to be valuable will persist, while information that is not used will be removed (or archived to a server that itself can serve as a domain agent).
- The semantic field will lead to message agents naturally congregating at certain network agents based on their signatures. Such concentrations will strengthen the semantic field around those network agents, enabling other message agents to find them more easily. Thus the system naturally self-organizes to provide efficient access to related information.
- The flow of currency through the system is a natural way to monitor the value contributed by different components. For example, network agents that accumulate more usage fees than others could use these fees to supplement their physical resources, thus guiding infrastructure investments based on actual usage patterns.
- Perhaps most important, the system eases the cognitive load on human domain agents. Information producers do not need to know who could use their products, nor do consumers need to know whom to ask. Users simply introduce message agents into the system, and the system will tell them when those packets of information have encountered other packets that might be useful to them. Instead of a synchronous process of query and response driven by human action, the system learns the interests of its users



and proactively helps them find both information and other users that can support their activities.

## SUMMARY

Current information management systems are constrained by assumptions developed in the days of stand-alone computer systems, or even pre-computer paper and ink repositories. These systems cannot accommodate the dynamic requirements of today's military. Fortunately, new computing technologies, such as stochastic filtering, living ontologies, and active information, permit us to challenge the old assumptions and develop new systems that offer a revolutionary advance in effectiveness and efficiency. The Altarum Institute has demonstrated many of these technologies in its research programs, and is actively pursuing their deployment in real-world applications.

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## Dynamic Team Management for Cross Organizational Collaboration

David Waxman, Industry Solutions  
John Park, Federal Software

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## Operating in an Event Driven Environment

- “On the first of February 2003, space shuttle falls out of the sky. Within 90 minutes, we had to set up a critical information exchange environment with 15 organizations that we had not even so much as made a phone call to. What elements of planning can you do when you don't even know who your partners are on an event-driven basis?”
- “You have to figure out how to dynamically create trusted information exchange environments, dynamically manage them, and have them go away when no longer required”
- “Tomorrow at lunch, I'm going to address the semi-annual meeting of the National Institute for Urban Search and Rescue. How many of those folks you think have a classification or clearance of some kind? I've got news for you. There are 2.5 million of those folks who potentially, depending on the event, I have to exchange information with”

Quotes from MG Meyerrose (NORTHCOM) to the JWID Final Planning Conference (FPC) in Chesapeake, VA on Tuesday 30 March 2004



## The Dynamic Team Management Solution

- The Dynamic Team Management (DTM) Solution is comprised of two COTS components
  - Integrated Directory Services
  - Collaborative Tools
- DTM was assembled by IBM in cooperation with DISA and MITRE to support participating organizations in the Homeland Security/Homeland Defense Command and Control Advanced Concept Technology Demonstration (HLS/D C2 ACTD)



## Domains Of Participants

<b>DoD:</b>	NORTHCOM DIRA SPAWAR-ITC	JFCOM DISA MTAC	USN Ops Ctr OSD JF HQ HLS	USMC Ops Ctr NCIS JTF-CS
<b>INTEL:</b>	DIA JITF-CT	CIA	NSA	NIMA
<b>DHS:</b>	US Coast Guard	NIPC	US Border Patrol	FEMA
<b>FEDERAL LE:</b>	DoJ DoT	FBI ATF	US Marshals NIPC	JTTF
<b>STATE:</b>	LA State OEP LA State Police	VA State EOC	WA State OEM	
<b>NATIONAL GUARD:</b>	National Guard Bureau	Virginia NG	Louisiana NG	Washington NG
<b>LOCAL:</b>	NYC	Port of Baton Rouge	Norfolk EOC	Chesapeake EOC Chesapeake FD
<b>COUNTY:</b>	Pierce County WA DEM	Pierce County Sheriff		
<b>BASES:</b>	NS/NAS/Norfolk	NS North Island	MCAS Miramar	MCB Camp Pendleton
<b>COMMERCIAL:</b>	IBM SAIC Grove	NuParadigm First Virtual ESRI	Swan Island Networks Nokia	Infrarworks BAE Systems NPTI (Florida)

## DTM Implementation in JWID 04'

- Joint Warrior Interoperability Demonstration (JWID 04')
- June 04'
- Dynamic Team Management addresses HLD/Military Assistance to Civil Authorities (MACA) mission requirements for ad hoc collaboration with organizations outside the military enterprise.
- DTM Locations
  - NORTHCOM – Colorado Springs, CO
  - DISA Eagle – Falls Church, VA
  - NSWC Dahlgren – Dahlgren, VA
  - Hanscom AFB – Bedford, MA

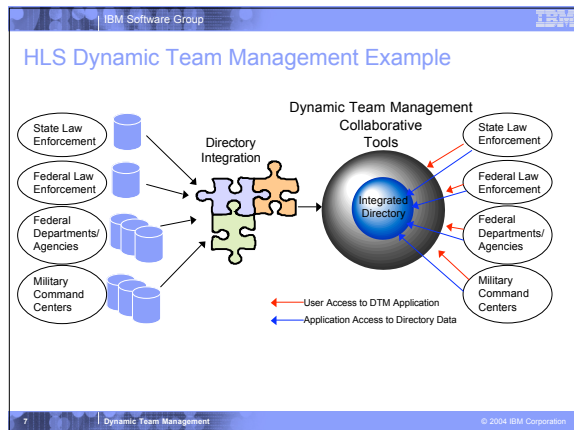
## Dynamic Team Management

- **Locate**  
In preparation for, during, or in response to an event, **rapidly assemble a team, across agency boundaries**, based on a variety of factors (name, department, role, geography, skill etc)
- **Invite**  
Using information provided during the location of those individuals or roles, invite them to collaborate
- **Authenticate**  
Using authentication information previously available or now provided, authenticate those individuals or roles
- **Collaborate**  
Working together, synchronously or asynchronously to solve a problem

## Dynamic Team Management Challenges

- Accommodating differing directory formats, schemas, and vocabulary
- Flexibly address directory sharing requirements/restrictions
- Maintaining currency of directory information
- Scaling collaboration as the situation evolves
- Locating the proper individuals/roles (expertise, responsibility) when team building
- Communicating/collaborating with organizations that you have never worked with before
- Avoiding one focal/choke point within an organization (single point of failure)
- Communicating via roles as well as individuals
- Capturing organizational reporting relationships
- Enable applications to leverage integrated directory information





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## Dynamic Team Management Components

- Integrated Directory Services Component**
  - Integrate Directories across agency, company, and organizational boundaries, utilizing the native format and schema of the data
  - Provide the Directory information to other applications via LDAP and Web Services
- Collaborative Tools Component**
  - Locate Individuals or Roles based on a variety of methods (name, organization, department, e-mail address etc.)
  - Constructing custom teams of individuals to support particular missions or tasks, based on emerging needs
  - Invite those team members to collaborate synchronously or asynchronously
  - Team Members login and participate to solve problems

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- ## Scenarios supporting "event driven" operations
- 1 - Pre Integrated**  
 Organizations that have agreed, ahead of time, to integrate their directories
  - 2 - Dynamic Assembly (business rules pre-determined)**  
 Organizations that have agreed, ahead of time, that their directory information is only to be used in conjunction with a pre-defined event.
  - 3 - Dynamic Assembly (ad hoc determination of business rules)**  
 Integrating an Organization's directory without any prior notice, "on the fly"
  - 4 - Manual Entry**  
 Supporting those organizations who, for a variety of reasons (security, connectivity) cannot or will not share components of their directory, and must be supported in another manner
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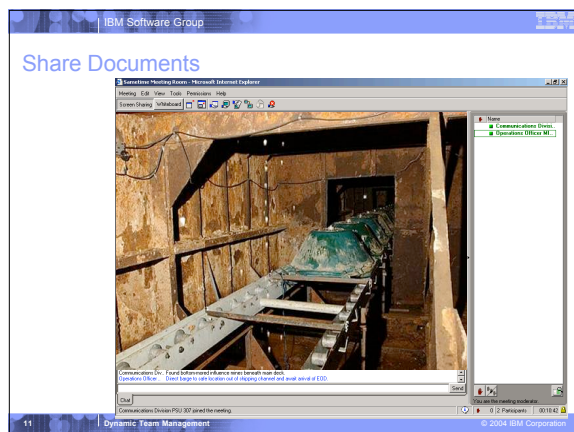
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## Collaborative Tool Portal

The screenshot shows the Collaborative Tool Portal interface. Four numbered steps are overlaid on the interface: 1. Locate (pointing to the search bar), 2. Invite (pointing to the 'Add Members to Team' button), 3. Authenticate (pointing to the 'Log In' button), and 4. Collaborate (pointing to the 'Collaborate' button). The interface includes a search bar, a list of team members, and a sidebar with various tool icons.

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## Advanced Search

The screenshot shows the 'Advanced Search' interface. It contains a detailed search form with multiple fields for filtering results. The fields include: First name, Last name, Description of position, Agency Name, Agency Type, Other, State or province, E-mail address, Phone number(s), Cell phone number(s), Pager number, Fax number(s), Account(s), Office location, Building, Room number, Street, Postal code, Country, and DTM login. There are also buttons for 'Search' and 'Clear'.

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